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EVALUATION OF THE ABUNDANCE OF THE SPECIES ADONIS VERNALIS IN THE TÂRNAV PLATEAU USING MODERN TECHNOLOGIES

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Abstract

The great diversity of orographic, climatic and pedological conditions encountered in the area of permanent grasslands in Romania gives them great heterogeneity in terms of floristic composition, production and forage quality.
The presence of the Carpathian Mountains causes a profound change in the climatic conditions and, therefore, in those of the soil and vegetation.
The purpose of the research is: assessment of habitats and abundance of the species Adonis vernalis from 2 different resorts.
The objectives pursued were the following: characterization of the floristic composition and biodiversity of the 2 habitats; assessment of the abundance of the Adonis vernalis species by quantifying all individuals.

Keywords: *Adonis vernalis, Blaj, biodiversity, abundance, grasslands management*

INTRODUCTION

The flora and vegetation of the Târnave Plateau (Transylvanian Plateau) has not been the subject of a complex and in-depth study to date. This territory, dominated by low-altitude hills and mountains, does not seem to be an area where spectacular floristic results can be recorded. Until now, it has not attracted the attention of specialists. However, contrary to expectations, the presented territory shelters an extremely rich flora, namely a varied grassland canopy, due to the geomorphological factor, which constitutes a contact region that extends in the vicinity of the plain region and to the fact that it is an interference zone into which floristic elements from very different geographical regions have penetrated. The most studied region is the Natura 2000 site Sighișoara - Târnava Mare, which has an exceptional scientific value at an international level. This is reflected both in terms of landscape and species diversity. The spring buttercup (*Adonis vernalis*) is a perennial herbaceous plant, from the Ranunculaceae family, known under several popular names: horse-weed, talan weed, black weed, etc. It is a melliferous, decorative, medicinal, but also toxic plant. Its toxic principles are adonitoxin, which contains coumarin and a coumarin derivative, vernadine. By drying the toxicity of the plant is preserved, and by boiling the toxicity disappears. Animals that consume the plant manifest toxic sensitivity, consisting of gastroenteritis with rebellious diarrhea, polyuria, cardiovascular disorders externalized by accelerated pulse, then slowed down, heart failure, pale mucous membranes, collapse, convulsions, depression and their death. In humans, excess treatment with this plant leads to intoxication manifested by nausea, vomiting, diarrhea, cardiac arrest and even death. Treatment is with emetics, purgatives, activated charcoal and cardiac analeptics (Habel *et al*, 2013). Only the aerial parts are harvested, during flowering, which are used in both human and veterinary medicine, to treat dropsy and migraines. They have cardiotonic and diuretic, calming, slightly hypertensive action. It gives good results in the treatment of tachycardia, extrasystoles of nervous nature, arterial hypotension and neurovegetative disorders (Pârvu, 2010). *Adonis vernalis* grows on steep slopes, in dry, sunny pastures and meadows, from the plains to the mountains. Its distribution is limited by hydrological factors. Thus, it is distributed where less than 500 mm of precipitation falls per year. In Romania it is widespread in the plateau and hill areas, in the Romanian Subcarpathians. It is widespread in Central and Southern Europe, but also in Western Asia.

Adonis vernalis is a protected species, declared a Natural Monument, considered a Vulnerable Species (VU) on the National Red Lists (IUCN, since 2011); thus, the populations of this species require conservation measures. As a rare species of European flora, *Adonis vernalis* is listed in the Red Books or in the lists of protected plant species in Bulgaria, Hungary, Romania and Moldova. The anthropogenic impact on the *Adonis vernalis* species is materialized by: the expansion of arable land areas to the limit of the species' distribution, grazing, exploitation of the substrate of xerophilic meadows, where it is found (Niculescu *et al.,* 2023). One of the species with national and international conservation priorities is *Adonis vernalis*, a species characteristic of continental-Mediterranean xerothermal grasslands, belonging to the order *Festucetalia valesiaceae*. Most populations of *Adonis vernalis* have decreased considerably in size in many European countries in recent decades and, therefore, as a threatened species, it is maintained under the CITES agreement. The causes for which the species is threatened are complex. These include overexploitation of populations (intensive agricultural practices) or overenclosure of patches due to secondary succession of grasslands.

Some causes are also due to the biology and ecology of the plant. (Denisow *et al*., 2014).

The main purpose of this work is to evaluate the current state of habitats and abundance of the plant species *Adonis vernalis* in the Blaj area, a region of botanical interest from the point of view of biodiversity conservation. Through this research, it is aimed to obtain relevant data that will contribute to understanding the local ecology of the species, to substantiate some protection and conservation measures, as well as to highlight the role that the species *Adonis vernalis* plays within the studied ecosystems.

The specific objectives of this research are: characterizing the floristic composition and biodiversity of the two habitats studied - this characterization will allow the assessment of the degree of floristic diversity, the identification of any characteristic or invasive species, as well as the analysis of the ecological relationships existing between the component species of the habitat; evaluating the abundance of the *Adonis vernalis* species - where a rigorous quantification of individuals (bushes) from the two habitats will be carried out, using standard methods of inventory and ecological sampling.

MATERIAL AND METHOD

The Transylvanian Plateau, also called the Transylvanian Basin (45°40'-47°50' N and 23°00'-25 °40' E) is a hilly area in central Romania. The research activity was carried out on a representative grassland area, called Obârșia Tiurului, in the Blaj locality. Blaj municipality is located at 23º55' east longitude and 46º10' north latitude, which gives it a relatively central position within the country. This brings it multiple advantages, such as: advantageous economic connections with the centers of the Târnavelor Plateau, the Apuseni Mountains, the Southern Carpathians and the Mureș Corridor. Blaj municipality is located in the eastern part of Alba county (www.primariablaj.ro).

To determine the floristic composition of the grassland in the Târnavelor Plateau, a study was needed for which 2 floristic surveys were carried out, using the Braun-Blanquét method modified by Păcurar and Rotar, in 2014, with three sub-notes and three sub-intervals, applied on 2 surfaces, each of 320 m^2. To evaluate the abundance of the plant species *Adonis vernalis*, 32 variants of 10 m^2 were delimited in each of the 2 plots/experiments, where each individual was counted (Figure 1).

Fig. 1 Original photo plot 1 and 2

Additionally, at the time of each floristic survey, using the GPS (Global Positioning System) device, data were recorded regarding the altitude (in meters, above sea level) and the exposure (in degrees, 0 – 360^{o}) of the survey research point (Kent 2012).

Vegetation research using this method is carried out in 3 stages:

1. determining the extent of the phytocenosis and establishing the survey area.
2. compiling the survey: noting on the ground in a geobotanical sheet the following information:

• current survey number, name of the grassland body and the locality (county, commune), within whose radius it is located.

• survey area.

• altitude, exposure, slope (degrees or percentages), relief, characterization of the resort (erosion, salinization, etc.).

• general vegetation coverage, in percentages.

• height and vegetation layering.

• observations on vegetation dynamics, etc.

The floristic list alone is not sufficient to characterize a phytocenosis, therefore the main geobotanical indices are assessed and recorded. The requirements of plants for ecological factors (light, temperature, soil moisture, soil reaction and nitrogen) were specified by species indicator values (from 1 to 9), according to (Ellenberg, 1998) updated by the Federal Agency for Nature Conservation, Germany (Bundesamt für Naturschutz – www.floraweb.de) and adapted to the conditions of our country by Kovács (1979). As specific names of species depending on the ecological categories of a factor, those developed by Păcurar and Rotar were used. Using descriptive statistics, analyses were carried out that are divided into two categories: central tendency parameters and data dispersion indicators. The central tendency parameters include those procedures that provide a representative (central) value for the measured data series. There are three estimators that can be used in this regard: mean, median and mode. Monitoring the *Adonis vernalis* species with the help of a drone - the flights were carried out using the DJI Matrice300 RTK drone. With its help, photographs were taken from 25 m height, 30 m, 40 m, and from 120 m, to determine the number of individuals of the *Adonis vernalis* species from the photographs as well. Thus, the data and photographs obtained can be processed in the office at any time and do not require accelerated field research due to the very short vegetation period of the plant.

RESULTS AND DISCUSSIONS

Within the perimeter of Obârșia Tiurului commune, 2 plots were studied, different in type of grassland, as follows (figure 2):

Obârșia Tiurului _1 - grassland type *Stipa pennata* – *Festuca rupicola*

Obârșia Tiurului _2 - grassland type *Stipa pennata* – *Koeleria macrantha* (figure 3).

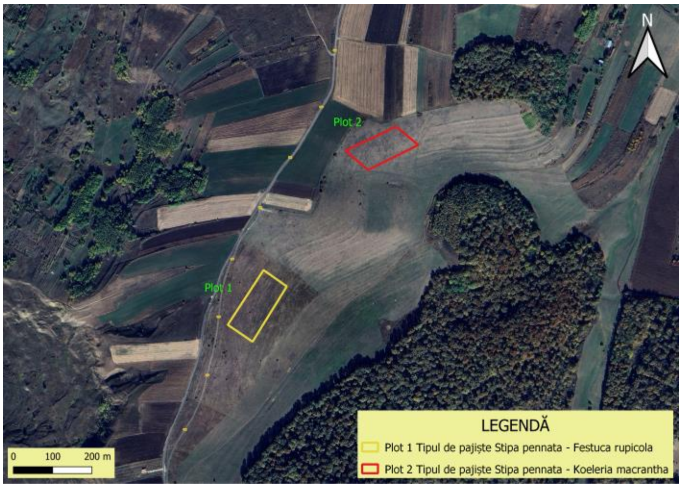

Fig. 2 Delimitation of plots on the Obârșia Tiurului grassland

Fig. 3 Photo of the pasture of Obârșia Tiurului _1

In the first plot, from this grassland, the *Stipa pennata* – *Festuca rupicola* type was identified, present on a land with a slope of 20-25% and South-West exposure. The general vegetation coverage of the phytocenosis is 70%, the coverage with woody vegetation is 5-6%, and that with is fresh molehills 3-4%. The degree of vegetation consumption is 30-35% (table 1, figure 4).

Table 1

Condiții staționale ale pășunii Obârșia Tiurului 1

Survey code	**Obârșia Tiurului _1**
Locality	OBÂRȘIA TIURULUI
Grassland plot	Obârșia Tiurului
Altitude (m)	357
Slope (°)	20-25
Exposition	S-V
Land use	Pășune
Grassland type	***Stipa pennata – Festuca rupicola***
General cover (%)	70
Wooden vegetation cover (%)	5-6
Fresh molehills (%)	3-4
Erosion (%)	2-3
Consumption rate (%)	30-35

In the floristic composition of the *Stipa pennata – Festuca rupicola* grassland type, Poaceae have the largest share in the canopy, with an average participation of 43%. Plants from other botanical families (AFB) are present in a proportion of 27%, species from the Fabaceae family have a coverage of 3.5%, and species from the *Cyperaceae – Juncaceae* family are absent from the grassland.

The phytocenosis of the *Stipa pennata – Festuca rupicola* grassland type has 20 species in its floristic composition. Among the Poaceae, in addition to the dominant species, *Stipa bromoides* also appears, with 12.5% coverage. Among the plants from other botanical families, the following species stand out: *Adonis vernalis* (12.5%), *Stachys germanica* and *Thymus glabrescens*, each with a share of 5% in the grassland canopy (table 2).

Table 2

Floristic composition of the type of grassland *Stipa pennata – Festuca rupicola* and specific requirement on ecological, agronomic and anthropogenic (B - BioForm, T - temperature, U - humidity, R - soil reaction, N – nutrition, C - tolerance of mowing, P - tolerance of grazing, S - tolerance of crushed, OBF-other botanical family)

Ecological indexes					**Agronomical indexes**			**Species**	Coverage	**Is**	**Is*%**
L	**T**	**U**	**R**	**N**	**C**	**P**	**S**				
								Poacee	**43**		
8	7	3	8	2	-	-	-	*Festuca rupicola*	12.5	1	12.5
6	X	5	x	X	9	8	8	*Poa pratensis*	0.5	4	2
-	-	-	-	-	-	-	-	*Stipa bromoides*	12.5	-	0
8	7	2	8	2	-	-	-	*Stipa pennata*	17.5	X	0
								Fabacee	**3.5**		
8	7	2	7	2	-	-	-	*Astragalus monspensulanus*	0.5	1	0.5
6	6	4	3	2	-	-	-	*Cytisus negricans*	0.5	X	0
8	5	3	9	3	7	2	2	*Medicago sativa*	2.5	4	10
7	x	X	x	X	7	4	4	*Trifolium pratense*	0	4	0
								OBF	**27**		
7	6	3	7	1	-	-	-	*Adonis vernalis*	12.5	X	0
7	6	X	7	x	4	4	4	*Convolvolus arvense*	0.5	3	1.5
8	6	5	7	3	-	-	-	*Eryngium planum*	0.5	X	0
6	x	5	7	7	-	-	-	*Euphorbia helioscopia*	0.5	X	0
-	-	-	-	-	-	-	-	*Filipendula hexapetala*	0.5	-	0
7	x	5	x	6	-	-	-	*Fragaria vesca*	0.5	1	0.5
-	-	-	-	-	-	-	-	*Gallium octonarium*	0.5	-	0
9	7	1	9	1	-	-	-	*Salvia nutans*	0.5	X	0
7	6	3	8	X	-	-	-	*Stachys germanica*	5	X	0
8	7	2	8	2	-	-	-	*Teucrium polium*	0.5	X	0
8	6	3	6	3	-	-	-	*Thymus glabrescens*	5	X	0
-	-	-	-	-	-	-	-	*Veronica praecox*	0.5	-	0
								$\sum$	**72**	**-**	**27**
								Number of species	**20**		

From the point of view of fodder value, the *Stipa pennata - Festuca rupicola* type belongs to the category of grassland unsuitable for grazing and supports a load of 0.20 livestock unit (LU) per ha (table 3).

Table 3

Classification of the *Stipa pennata-Festuca rupicola* grassland type

Improvement coefficient for			Note of improving	The grassland class	The category of grassland	Grazing capacity (LU/ha)
Patoral value	Cover with molehills	Woody vegetation cover				
0.27	1	1	10	X	Improper	0.20

Regarding *Stipa pennata-Festuca rupicola* type, it is noted, according to the species' requirements for ecological factors:

9 heliophile species, one heliophilous species and one extremely heliophilous species. If we also take into account the cover, the phytocenosis has a heliophilous character. According to temperature preferences, we have 6 mesothermal species, 4 thermophilic species and 3 indifferent species, and the hierarchy remains the same when taking into account the cover. The plants' requirements for humidity determine the presence of 5 mesoxerophilous species, 4 mesophilic species, 3 xerophilous species and one indifferent species. The character of the phytocenosis is a mesoxerophilous one (table 4).

Table 4

Plant requirements for ecological factors

Interval	Light		Temperature		Humidity	
	No. sp.	A%	No. sp..	A%	No. sp.	A%
1-2	-	-	-	-	3	1,5
3-4	-	-	-	-	5	2
5-6	1	1,5	6	4	4	2
7-8	9	27,5	4	14	-	-
9	1	0,5	-	-	-	-
X	-	-	3	1,5	1	0,5
Total	11	29,5	13	19,5	13	6

Legend:No. sp-number of species, A-cover%

Regarding the species' nitrogen requirements, we have: 6 nitrogen-fugitive species, 3 moderately nitrophilic species and 3 indifferent species, one medium-nitrophilic species and one nitrophilic species. Taking into account the cover, the character of the phytocenosis is nitrogen-fugitive (table 5).

Table 5

Plant requirements for nitrogen content

Interval	**Number of species**	**Coverage%**
1-2	6	32
3-4	3	8
5-6	1	0.5
7-8	1	0.5
9	-	-
X	3	6
I	-	-
Total	14	47

Regarding the species' requirements for soil reaction, it is found that we have 6 alkaliphilic species, 4 neutrophilic species, 2 indifferent species, one moderately acidophilic species and one weakly acidophilic species. In the case of general cover, the character of the phytocenosis is alkaliphilic (table 6).

Table 6

Plant requirements for soil reaction

Interval	Number of species	Coverage%
1-2	-	-
3-4	1	0.5
5-6	1	5
7	4	2
8-9	6	38
X	2	1
I	-	-
Total	14	60.5

In the second plot, from this body, the type of grassland *Stipa pennata – Koeleria macrantha* was identified, present on a land with a slope of 20-25% and a Southern exposure. The general vegetation coverage of the phytocenosis is 75%, the woody vegetation coverage is 2-4%, and the one with molehhils is 1-2%. The degree of vegetation consumption is 30% (table 7, figure 4).

Fig. 4 Photo of the pasture of the Tiur origin _2

Table 7

Stationary conditions of the Obârşia Tiurului pasture 2

Survey code	Obârşia Tiurului _2
Locality	OBÂRŞIA TIURULUI
Grassland plot	Obârşia Tiurului
Altitude (m)	407
Slope (°)	20-25
Exposition	S
Land use	Păşune
Grassland type	***Stipa pennata – Koeleria macrantha***

General cover (%)	75
Wooden vegetation cover (%)	2-4
Fresh molehills (%)	1-2
Erosion (%)	2-3
Consumption rate (%)	30

In the floristic composition of the *Stipa pennata – Koeleria macrantha* grassland type, Poaceae have the largest share in the canopy, with an average participation of 47.5%. Plants from other botanical families (AFB) are present in a proportion of 24.5%, species from the Fabaceae family have a coverage of 1.5%, and species from the Cyperaceae – Juncaceae family are absent from the vegetal cover. The phytocenosis of the *Stipa pennata – Koeleria macrantha* grassland type has 18 species in its floristic composition. Among the Poaceae, in addition to the dominant species, *Brachypodium pinnatum* also appears, with 5% coverage. Among the plants from other botanical families, the following species stand out: *Adonis vernalis* (17.5%), *Veronica austriaca, Achillea millefolium, Agrimonia eupatoria,* etc., each with a share of 0.5% presence (table 8).

Table 8

Floristic composition of the type of grassland *Stipa pennata – Koeleria macrantha* and specific requirement on ecological, agronomic and anthropogenic (B - BioForm, T - temperature, U - humidity, R - soil reaction, N – nutrition, C - tolerance of mowing, P - tolerance of grazing, S - tolerance of crushed, OBF-other botanical family)

Ecological indexes					**Agronomical indexes**			**Species**	**Coverage**	**Is**	**Is*%**
L	**T**	**U**	**R**	**N**	**RC**	**RP**	**RCA**				
								Poacee	**47.5**		
6	5	4	7	4	3	6	6	*Brachypodium pinatum*	5	1	5
7	6	3	7	2	-	-	-	*Koeleria macranta*	17.5	X	0
6	X	5	x	X	9	8	8	*Poa pratensis*	0.5	4	2
8	7	2	8	2	-	-	-	*Stipa pennata*	25	X	0
								Fabacee	**1.5**		
8	7	2	7	2	-	-	-	*Astragalus monspensulanus*	0.5	1	0.5
7	6	3	5	2	-	-	-	*Cytisus albus*	0.5	X	0
7	x	4	7	4	6	4	4	*Lotus corniculatus*	0.5	4	2
								OBF	**24.5**		
8	x	4	x	5	7	4	5	*Achillea millefolium*	0.5	2	1
7	6	3	7	1	-	-	-	*Adonis vernalis*	17.5	X	0
7	6	4	8	4	3	4	3	*Agrimonia eupatoria*	0.5	X	0
7	6	X	7	x	4	4	4	*Convolvulus arvense*	0.5	3	1.5
9	7	3	8	4	-	-	-	*Eryngium campestre*	0.5	X	0

7	x	5	x	6	-	-	-	*Fragaria vesca*	0.5	1	0.5
7	x	4	8	3	4	8	8	*Plantago media*	0.5	1	0.5
6	6	6	7	5	8	4	5	*Potentilla reptans*	0.5	X	0
8	6	3	7	3	-	-	-	*Salvia nemorosa*	0.5	X	0
8	6	3	6	3	-	-	-	*Thymus glabrescens*	0.5	X	0
8	7	2	8	1	-	-	-	*Veronica austriaca*	2.5	-	0
								∑	**74**	-	**13**
								Număr specii	**18**		

From the point of view of fodder value, the type *Stipa pennata - Koeleria macrantha*, belongs to class X, a category unsuitable for grazing and supports a load of 0.20 LU/ha (table 9).

Table 9

Classification of the grassland type Stipa pennata - Koeleria macrantha

Improvement coefficient for			Note of improving	The grassland class	The category of grassland	Grazing capacity (LU/ha)
Patoral value	Cover with molehills	Woody vegetation cover				
0.13	1	1	10	X	Improper	0.20

The light requirements of the plants determine the following structure: 11 heliophiles species, 3 meso-heliophilous species and one extremely heliophilous species. The heliophilous character of the phytocenosis is evident from the coverage. The temperature requirements determine the following division: 7 mesothermal species, 5 indifferent species and 3 thermophilic species, and according to the degree of coverage it is evident that the phytocenosis has a mesothermal character. Depending on the humidity requirements, the species are structured as follows: 9 mesoxerophilous species, 3 mesophilic species, 2 xerophilous species and one indifferent species (table10).

Table 10

Plant requirements for ecological factors

Interval	Light		Temperature		Humidity	
	No. sp.	A%	No. sp..	A%	No. sp.	A%
1-2	-	-	-	-	2	3
3-4	-	-	-	-	9	9
5-6	3	6	7	8	3	1,5
7-8	11	7,5	3	3,5	-	-
9	1	0,5	-	-	-	-
X	-	-	5	2,5	1	0,5
Total	15	14	15	14	15	14

The species' requirement for nitrogen content determines the following structure: 6 moderately nitrophilic species, 4 nitrogen-fugitive species, 3 moderately nitrophilic species and 2 indifferent species. The character of the phytocenosis is nitrogen-fugitive (table 11).

Table 11

Plant requirements for nitrogen content

Interval	Number of species	Coverage%
1-2	4	28.5
3-4	6	7.5
5-6	3	1.5
7-8	-	-
9	-	-
X	2	1
I	1	17.5
Total	16	56

The plant requirements for soil reaction determined the following structure: 5 alkaliphilic species, 5 neutrophil species, 3 indifferent species and 2 weakly acidophilic species. The character of the phytocenosis is alkaliphilic (table 12).

Table 12

Plant requirements for soil reaction

Interval	Number of species	Coverage%
1-2	-	-
3-4	-	-
5-6	2	1
7	5	7
8-9	5	29
X	3	1.5
I	1	17.5
Total	16	56

Effective monitoring of the species *Adonis vernalis*

In all 32 plots of Plot 1, *Adonis vernalis* individuals were identified. The least number was one plant/25 m^2, and the most was 165 plants/25 m^2. The variability within our experience is very high (CV = 0.84), and the coefficient of variability indicates that the median is representative. The median in this plot was 49 individuals, and the mean was 63. A moderately asymmetric distribution (Skuness = 0.44) is observed, and the skewness (Kurtosis = -1.14) is platokurtic (table 13).

Table 13

Abundance of the species *Adonis vernalis* (no. of individuals/25m^2; Plot 1)

PLOT 1							
1	1	1	14	94	115	110	156
7	16	53	92	165	124	105	154
4	16	40	55	129	121	96	93
9	11	8	24	44	49	49	47
STATISTICS							
Minim	1						
Maxim	165						
CV	0.84						
Median	49						
Average	62.59						
The vaulting	-1.14						
Asymmetry	0.44						
Standard deviation	52.69						

In all variants of Plot 2, *Adonis vernalis* individuals were identified. The least number was 5 plants/25 m^2, and the most was 197 plants/25 m^2. The variability within our experience is very high (CV = 0.73), and the coefficient of variability indicates that the median is representative. The median in this plot was 80 individuals, and the mean was 83. A moderately asymmetric distribution (Skuness = 0.22) is observed, and the kurtosis (Kurtosis = -1.30) is platokurtic (table 14).

Table 14

Abundance of the species *Adonis vernalis* (no. of individuals/25m2; Plot 2)

PLOT 2							
7	5	25	53	92	133	126	166
34	30	33	102	145	142	121	132
9	7	20	45	119	173	183	197
7	9	49	59	75	85	127	138
STATISTICS							
Minim	5						
Maxim	197						
CV	0.73						
Median	80						
Average	82.75						
The vaulting	-1.30						
Asymmetry	0.22						
Standard deviation	60.57						

Results of monitoring flights of the species *Adonis vernalis*

Following the flights carried out in April 2023, it was found that the plants can be easily identified from the images taken from heights of 25 m and 30 m (figure 5). From the images from 40 – 60 m, the plants can only be identified if the photo is enlarged (with Zoom) (figure 6). Above 60 m (60 – 120 m), *Adonis vernalis* individuals are difficult to distinguish and with a high degree of error (figure 7). These things were observed in both plots.

Fig. 5 Original drone photo (25m)

Fig. 6 Original drone photo (50 m)

Fig. 7 Original drone photo (100 m)

CONCLUSIONS

Following field studies, 2 types of grassland were identified:

- the *Stipa pennata* type - *Festuca rupicola* has a heliophilic, mesothermal, mesoxerophilic, nitrogen-loving, alkalinophilic character;

- the *Stipa pennata* type - *Koeleria macrantha* has a heliophilic, mesothermal, mesoxerophilic, nitrogen-loving and alkalinophilic character.

Both types are part of the X-th grassland class, a category unsuitable for grazing and support a load of 0.20 LU/ha.

The abundance of the *Adonis vernalis* species differs from one plot to another, presenting a high variability. Thus, the presence of the species was on average 63 plants/25m^2 in Plot 1 and 83 plants/25m^2 in Plot 2.

Photographing the plots and counting *Adonis vernalis* individuals from the office can only be done if the drone flights are made at a height of 25 – 30 m.

The plant can be successfully harvested and used as a medicinal plant because it is present in a fairly large proportion in grassland

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STUDIES ON THE ECOLOGICAL RESTORATION OF GRASSLAND ECOSYSTEMS AT THE PĂLTINIȘ EXPERIMENTAL STATION

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Abstract

The restoration of degraded grassland is a necessary in Romania. Different management of a grassland, such as mulching, can lead to major changes in its composition. The research took place in the Cindrel Mountains, in Păltiniș, on two experimental plots. This paper shows how in just 2 years of mulching the floristic composition changes, the type of grassland being different, at the same time, it is shown that species are disappearing from the conopy. The information provided by species with indicator value can overlap and, in this way, valuable information can be obtained regarding the stationary conditions of a particular phytocenosis and the intensity of management.

Keywords: Mulch, Cindrel Mountains, restoration, Paltinis, biodiversity of grasslands

INTRODUCTION

Romania's Mountain area has a rich, valuable and relatively well-preserved natural resource base. Romania's Mountains host some of the largest expanses of primary and old-growth forests and traditionally managed grasslands in Europe and are important reservoirs of biodiversity. Together with climate change, depopulation and abandonment in mountain areas and mountain farming in Romania have endangered the balance, health, productivity and biodiversity of traditionally managed grassland systems, which depend on the interaction between humans, domestic animals and wildlife. In this context, a new politics governance is urgently needed to reverse the decline and conserve the management of grassland ecosystems by combining traditional practices with modern evidence and technologies (Horablaga *et. al* 2023; Yang *et. al*, 2024). Grassland ecosystems (HNVs) need a clearer picture, which can be elucidated by analyzing indicators of agricultural management combined with those of biodiversity assessment (Krautzer and Pötsch, 2009; Óhuallacháin *et al.*, 2018). In Eastern Europe, extensively managed semi-natural grasslands are considered hotspot of biodiversity, some of them even of major international importance, competing with habitat diversity that hold world records in the number of species per unit area (Wilson *et al.*, 2012). These, for the most part, have been maintained by agricultural practices, thus their phytodiversity has developed over centuries in close correlation with the type of management applied (Habel *et al.*, 2013; Rotar *et al.*, 2012). Ecological reconstruction of degraded grasslands is a topic of major importance in the context of biodiversity conservation and restoration of natural ecosystems. In this regard, the present work focuses on the ecological reconstruction of grasslands at the Paltiniș Experimental Station, with the main aim of the effect of mulching on abandoned grasslands. Grassland degradation is a common phenomenon in grassland ecosystems, and the aim of this study is to identify the most effective techniques for their restoration in order to improve the quality and diversity of vegetation in the study area.

MATERIAL AND METHOD

Our studies were carried out at the Păltiniș resort, the experiments were located on the Noth-Est ridge of the Cindrel Mountains, near the resort of Paltinis, at an altitude of 1,348 m. The soils in the area are submesosotrophic and brown-acidic. The Cindrel Mountains cover an area of about 900 km^2 with a maximum altitude of 2244 m (Cindrel Peak). The surface of the Cindrel Mountains forms a triangle with the apex towards Vârful Cindrel and two of the sides formed by the Sadu River, tributary of the Olt, which separates them from the Lotrului Mountains and the second side by the Frumoasa River and then by the Sebeș River, which separates them from the Șureanu Mountains (Anghel și Doniță, 1980).

The study was conducted on two experimental plots of abandoned grassland located within the research station, one of which was subjected to mulching treatment in 2021. Floristic studies were carried out using the geobotanical (phytosociological) method, which involves conducting phytocenological surveys (relevees) in the field.

For processing, the data obtained was entered into the form of two matrices. In the first matrix the vegetation data were entered and in the second matrix the experimental variants were coded. The program has tools for classification and ordination of vegetation and various randomization tests. The program also has possibilities for graphical representation of the results. The details of this program have been described by several authors (Mccune, 2002 and Peck, 2010).

Floristic data processing was performed with PC-ORD, version 7. For processing, the data obtained were entered as two matrices. In the first matrix the vegetation data were entered and in the second matrix the experimental variants were coded.

The program has tools for classification and ordination of vegetation and various randomization tests. The program also has possibilities for graphical representation of the results. The details of this program have been described by several authors (Mccune, 2002 and Peck, 2010).

RESULTS AND DISCUSSIONS

Following the classification using the PC-ORD program (version 7), a graphical representation (dendogram; fig. 1) was produced, which records how the floristic surveys are classified, but also indicates the distance between them. According to the literature, the level at which the dendogram will be cut, is where the resulting groups, make phytosociologically and ecologically justified sense, but also at a level at which as much information as possible remains (Peck, 2010). The floristic survey data were categorized by distance index, Euclidean.

After analyzing the floristic composition, we considered that cutting at 70 is the most optimal solution in our case, as it makes phytosociological, ecological and agronomic sense. Thus, two distinct clusters (Fig. 2) were identified, consisting of the following grassland types: *the Festuca rubra type* (cluster 1) and the *Festuca rubra - Agrostis capillaris* type (cluster 2). The formation of the clusters because of mulching shows that it has produced major changes in the vegetation cover. Thus, *Agrostis capillaris* is the co-dominant species under mulching conditions.

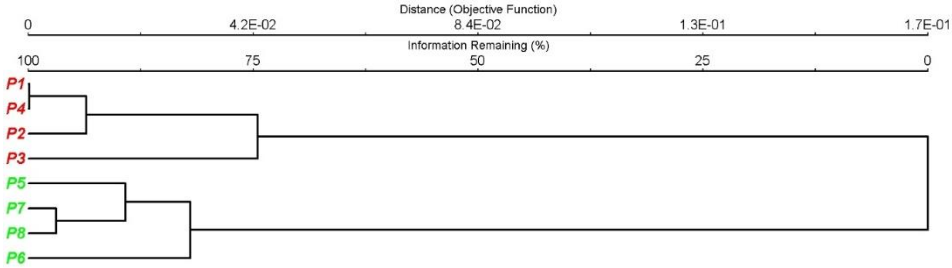

Fig. 1 Dendrogram of floristic composition classification

After ordination with principal coordinates analysis (PcoA), it was found that the floristic surveys were grouped according to similarity of floristic composition, stationary conditions and management applied (Fig. 2).

The phytocenosis of abandonment is represented by the *Festuca rubra* type, and with mulching, it evolves into the *Festuca rubra - Agrostis capillaris* type (table 1; T = - 4.450; A = 0.631; p = 0.005).

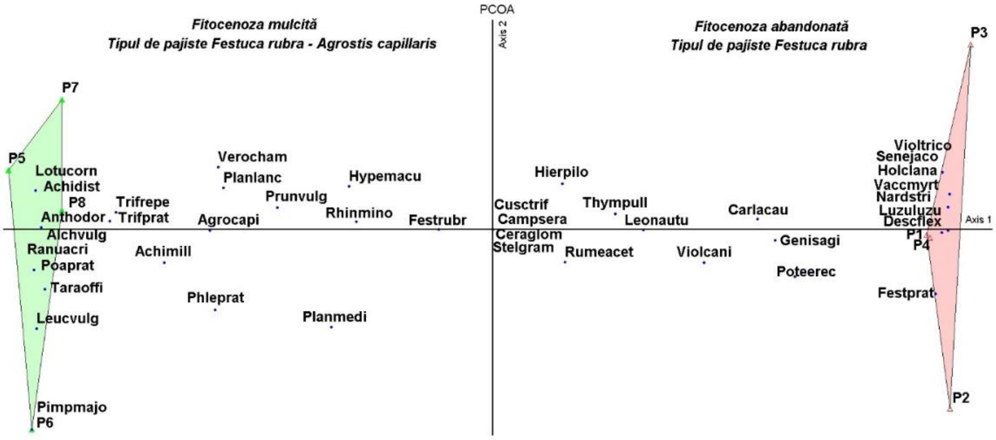

Fig. 2 Ordering phytocenosis according to management applied

LEGEND/ABBREVIATIONS			
Agrocapi	*Agrostis capillaris*	***Hierpilo***	*Hieracium pilosella*
Anthodor	*Anthoxanthum odoratum*	***Hypemacu***	*Hypericum maculatum*
Descflex	*Deschampsia flexuosa*	***Leonautu***	*Leontodon autumnalis*
Festprat	*Festuca pratensis*	***Leucvulg***	*Leucanthemum vulgaris*
Festrubr	*Festuca rubra*	***Pimpmajo***	*Pimpinella major*
Holclana	*Holcus lanatus*	***Planlanc***	*Plantago lanceolata*
Nardstri	*Nardus stricta*	***Planmedi***	*Plantago media*
Phleprat	*Phleum pratense*	***Poteerec***	*Potentilla erecta*
Poaprat	*Poa pratensis*	***Prunvulg***	*Prunella vulgaris*
Luzuluzu	*Luzula luzuloides*	***Ranuacri***	*Ranunculus acris*
Genisagi	*Genista sagitallis*	***Rhinmino***	*Rhinanthus minor*
Lotucorn	*Lotus corniculatus*	***Rumeacet***	*Rumex acetosella*
Trifprat	*Trifolium pratense*	***Senejaco***	*Senecio jacobea*
Trifrepe	*Trifolium repens*	***Taraoffi***	*Taraxacum officinalle*
Achidist	*Achillea distans*	***Thympull***	*Thymus pullegioides*
Achimill	*Achillea millefolium*	***Vaccmyrt***	*Vaccinium myrtillus*
Alchvulg	*Alchemilla vulgaris*	***Verocham***	*Veronica chamaedrys*
Carlacaulis	*Carlina acaulis*	***Violcani***	*Viola canina*
		Violtric	*Viola tricolor*

Table 1

Comparison between the floristic composition of the experimental variants (MRPP)

Treatments	T	A	p	Significance
Mulched vs. untreated or mulch	-4.450	0.631	0.005	**

T – T-test, A – group homogeneity, p - statistical significance
Significance: *** P<0.001; ** P<0.01; * P<0.05; ns – not significant

Mulching caused major changes in floristic composition which can be explained in a proportion of 99%, of which 97.7%

of the observed phenomenon can be explained by axis 1 ordination and 0.013% by axis 2 ordination (table 2).

Table 2

The importance of axes

Axis	Participation rate (r)	Cumulative
1	0.977	0.977
2	0.013	0.990

r - the coefficient of determination for the correlations between ordering distances and original distances in n-dimensional space

Some species (21) correlate with ordination axis 1 (negative zone) and axis 2 (positive zone), which means that they are favored by applied management - mulching (Table 3; Fig. 2). These include: *Agrostis capillaris* (p<0,001), *Anthonxantum odoratum* (p<0,001), *Trifolium pratense* (p<0,001), *Achillea distans* (p<0,001), *Plantago lanceolata* (p<0,001), *Ranunculus acris* (p<0,001) etc. Other species (16) correlate with axis 1 ordination (positive zone) and axis 2 (negative zone), they are favored by meadow abandonment, such as: Hieracium pilosella (p<0.001), Rumex acetosella (p<0.001) etc. The application of mulching caused the disappearance of some species and the appearance of others. The following species disappeared from the grassland: *Deschampsia flexuosa, Festuca pratensis, Senecio jacobea, Viola tricolor* and the following species were installed: *Anthoxantum odoratum, Poa pratensis, Alchemilla vugaris, Leucanthemum vulgare* (table 3). Indicator species are those that provide valuable information to the researcher on environmental conditions, application of maintenance and use, level of anthropogenic influence, etc. The information provided by indicator species can overlap and, in this way, valuable information can be obtained on the seasonal conditions of a particular phytocenosis and the intensity of management. Once the status of the phytocenoses is established, practical management strategies can be developed, including maintenance and use works appropriate for the purpose. For example, indicator species can be particularly useful for High Nature Value (HNV) grasslands, for which a clear picture and appropriate grassland management needs to be established (Krautzer and Pötsch, 2009). In our experience with mulch, based on the analysis of indicator species, it can be seen that the grassland type *Festuca rubra - Agrostis capillaris* has 10 indicator species in its floristic composition (Table 4). The majority of species in this group are oligotrophs and oligomotrophs. *Festuca rubra* (22.25%) has the highest coverage, followed by *Agrostis capillaris* (18.69%), *Achillea millefolium* (3.13%), etc., and *Achillea distans* (0.5%), *Ranunculus acris* (0.5%), etc., have the lowest coverage.

Table 3

Correlation of species with ordination axes

Species	Axis 1		Axis 2	
	r	**Significance**	***r***	**Significance**
Agrostis capillaris	-0.982	***	-0.011	ns
Anthoxanthum odoratum	-0.999	***	0.016	ns
Deschampsia flexuosa	0.958	***	-0.006	ns
Festuca pratensis	0.759	***	-0.395	*
Festuca rubra	-0.999	***	0.016	ns
Holcus lanatus	0.770	***	0.351	*
Nardus stricta	0.959	***	0.170	ns
Phleum pratense	-0.519	**	-0.541	**
Poa pratensis	-0.786	***	-0.250	ns
Luzula luzuloides	0.891	***	-0.023	ns
Genista sagitallis	0.860	***	-0.121	ns
Lotus corniculatus	-0.584	**	0.179	ns
Trifolium pratense	-0.953	***	0.076	ns
Trifolium repens	-0.937	***	0.151	ns
Achillea distans	-0.584	**	0.179	ns
Achillea millefolium	-0.867	***	-0.316	*
Alchemilla vulgaris	-0.999	***	0.016	ns
Carlina acaulis	0.755	***	0.105	ns
Hieracium pilosella	0.278	ns	0.655	***
Hypericum maculatum	-0.360	*	0.389	*
Leontodon autumnalis	0.999	***	-0.016	ns
Leucanthemum vulgaris	-0.638	***	-0.497	**
Pimpinella major	-0.385	*	-0.600	**
Plantago lanceolata	-0.769	***	0.426	*
Plantago media	-0.360	*	-0.781	***
Potentilla erecta	0.772	***	-0.434	*
Prunella vulgaris	-0.465	**	0.171	ns
Ranunculus acris	-0.999	***	0.016	ns
Rhinanthus minor	-0.627	***	0.130	ns
Rumex acetosella	0.480	**	-0.780	***
Senecio jacobea	0.770	***	0.351	*
Taraxacum officinalle	-0.721	***	-0.345	*
Thymus pullegioides	0.770	***	0.351	*
Vaccinium myrtillus	0.908	***	0.253	ns
Veronica chamaedrys	-0.621	***	0.506	**
Viola canina	0.467	**	-0.265	ns
Viola tricolor	0.770	***	0.351	*

r - correlation coefficient, Semnif. - Significance; Sign: *** P<0,001; ** P<0,01; * P<0,05; ns (0) P<0,10

The species *Anthoxanthum odoratum, Alchemilla vulgaris, Leucanthemum vulgare, Ranunculus acris, Taraxacum officinale* (100,0) have the highest indicator value (INDVAL). This is due to the maximum constancy (K) these species reach (K - 12). *Pimpinella major* species shows the lowest indicator value of 25%. The poor indicator value of these species is determined by their presence also in (different in constancy and participation) in the other phytocenoses.

In the abandoned grassland, based on the analysis of indicator species, the F*estuca rubra* grassland type has 6 indicator species in its floristic composition (Table 4). Most of the species in this group are oligotrophic and oligomeso-oligotrophic. *Festuca rubra* has the highest coverage (17.5%), followed by *Nardus stricta* (5.75%), etc., and *Vaccinium myrtillus* (3.13%) has the lowest.

Deschampsia flexuosa, Nardus stricta, Luzula luzuloides and Vaccinium myrtillus have the highest indicator value (INDVAL) (100.0). This is due to the maximum constancy (K) achieved by these species (K - 12*). Campanula serata, Cerastium glomeratum, Cuscuta trifolii,* etc. have the weakest indicator value of 50%. The weak indicator value of these species is determined by their presence also in the (different in constancy and participation) of the other phytocenoses.

Table 4

Indicator species for applied treatments

Specie	**T**	**INDVAL**	**Media**	**Dev. Std.**	**p**	**Semnif.**
Deschampsia flexuosa	1	100	42.3	18.15	0.032	*
Festuca pratensis	1	75	39.2	14.56	0.142	ns
Holcus lanatus	1	75	39.4	14.67	0.144	ns
Nardus stricta	1	100	43	17.43	0.032	*
Luzula luzuloides	1	100	43.9	16.96	0.032	*
Genista sagitallis	1	81.4	61	8.23	0.057	*
Campanula serata	1	50	50	0.71	1.000	ns
Carlina acaulis	1	80	49.9	12.15	0.139	ns
Cerastium glomeratum	1	50	50	0.71	1.000	ns
Cuscuta trifolii	1	50	50	0.71	1.000	ns
Hieracium pilosella	1	57.1	59.3	5.16	1.000	ns
Leontodon autumnalis	1	66.7	54.2	4.73	0.032	*
Potentila erecta	1	84.2	58.6	12.99	0.117	ns
Rumex acetosa	1	58.3	54.3	4.69	0.485	ns
Senecio jacobea	1	75	39.4	14.67	0.144	ns
Stellaria graminea	1	50	50	0.71	1.000	ns

Thymus pullegioides	1	63.6	55.8	3.29	0.144	ns
Vaccinium myrtillus	1	100	43.9	16.99	0.032	*
Viola canina	1	56.2	41.3	18.35	0.482	ns
Viola tricolor	1	75	39.4	14.67	0.144	ns
Agrostis capillaris	2	81	59.3	7.79	0.032	*
Anthoxanthum odoratum	2	100	41.3	18.67	0.032	*
Festuca rubra	2	56	51.5	1.82	0.032	*
Phleum pratense	2	80	58.5	14.16	0.282	ns
Poa pratensis	2	75	39.6	14.87	0.149	ns
Lotus corniculatus	2	50	28.6	18.56	0.428	ns
Trifolium pratense	2	92	63.9	9.67	0.032	*
Trifolium repens	2	92	63.7	9.61	0.032	*
Achillea distans	2	50	28.6	18.56	0.428	ns
Achillea millefolium	2	86.2	63.7	7.99	0.032	*
Alchemilla vulgaris	2	100	41.3	18.67	0.032	*
Hypericum maculatum	2	66.7	66.7	0.94	1.000	ns
Leucanthemum vulgare	2	100	47.8	17.08	0.032	*
Pimpinella major	2	25	25	0.35	1.000	ns
Plantago lanceolata	2	80	62.8	7.05	0.143	ns
Plantago media	2	68	66	10.24	0.725	ns
Prunella vulgaris	2	72.7	61.8	12.43	0.563	ns
Ranunculus acris	2	100	41.3	18.67	0.032	*
Rhinanthus minor	2	65.2	57.6	4.80	0.276	ns
Taraxacum officinale	2	100	44.4	19.05	0.032	*
Veronica chamaedrys	2	80	61.2	11.95	0.286	ns

Legend: T - applied treatment; INDVAL - indicator value; N - species preference to nitrogen; ADm - abundance - dominance - mean; Dev. Std - standard deviation; Signs: *** p<0.001; ** p<0.01; * p<0.05; ns - not significant

CONCLUSIONS

The Cindrel Mountains are characterized by dome-shaped long ridges, mostly covered with pastures, which have favored shepherding, the main occupation of the people living on the margins. The soil scattered throughout the massif is low fertility and acidic, with a wet and cool climate.

The effect of mulching on the grassland of *Festuca rubra* was seen from the second year after application.

The *Festuca rubra – Agrostis capillaris* type of grassland was established on the mulched plot, which is agronomically superior to the *Festuca rubra* type.

Mulch can be successfully used in the reconstruction of abandoned grassland in the Cindrel Mountains.

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THE PRATOTECHNICAL CONDITIONS IN THE BUCEGI MOUNTAINS WHERE THE NEW VARIETY OF *PHLEUM PRATENSE* "CARPATICA" WAS CREATED

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Abstract

In 1995, a three-factor experiment (fertilization, grassy carpet type, calcium amendment) was set up in the Bucegi Massif at an altitude of 1800 m, with outstanding results. After 26 years, Phleum pratense sown in a mixture of 40% participation survived almost 26% in the over-sown, amended and chemically fertilized variant, a fact less known in the literature. Mineral fertilization stimulated Phleum pratense species by 45-46% more than organic fertilization by hoeing. The main agrochemical factor on which the participation of Phleum pratense species in the grass carpet depended was the soil reaction after amendment. After 26 years (2018-2022) the participation of the Phleum pratense species in mineral fertilization is maintained at 25.6% on the amended soil after overseeding and 8.4% - respectively 3 times less after reseeding. In these extreme hydrothermal conditions and pratotechnical factors, 250 clones of Phleum pratense selected by "nature" at 1800 m were taken from the experimental field, which were introduced for 3 years in the improvement process at 600 m altitude at ICDP Braşov, from which 8 clones were selected for polycross the variety "Carpatica" which can achieve 12.7 t/ha of good quality DM t/ha, according to ISTIS Bucharest tests.

Keywords: improvement, subalpine grassland, variety, *Phleum pratense*, Carpatica", breeding process

INTRODUCTION

The creation of new varieties of perennial grasses for extreme climatic conditions and soils or substrates with poor physical and chemical properties is an essential objective both for the improvement of degraded grasslands and for ecological reconstruction due to natural factors or anthropogenic activities. In the area of the high mountains, the assortment of perennial grasses with good fodder quality and longevity is quite limited (Tod M. et all, 2015). The species of the spontaneous flora better adapted to the environmental conditions of the upper, subalpine and alpine floors such as *Festuca* *rubra, Festuca nigrescens* and *Festuca airoides* as initial breeding material have lower production and fodder quality performances than the better known species from the lower mountain area, hills and plains (Varga P. et all, 1998). Thus, the problem of identifying more productive and long-lived grasses outside the spontaneous flora of the high mountains was raised. During a long-term experience in the Bucegi Massif, the *Phleum pratense* species stood out for its longevity and quality, from which a new variety was created with special properties for improving meadows located at high altitudes, a problem that we are continuing to develop.

MATERIAL AND METHOD

The studies on the initial material for breeding activity were carried out at the "Teodor Maruşca" Mountain Grassland Research Base in Blana Bucegi, located at 1800 m altitude, in an experience of improving subalpine meadows degraded by *Nardus stricta* with the following:

The variants of the long-term experience (1995-2022) were:

Factor A: Fertilization

1. Mineral fertilization

Stage I: 1996 - 50 kg /ha P_2O_5 +50 kg/ha K_2O; 1997 - 50 kg /ha P_2O_5 +50 kg/ha K_2O; 1998 - 50 kg /ha P_2O_5 +50 kg/ha K_2O;

Stage II: 2004 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O; 2005 - 100 kg /ha N; 2006 - 50 kg /ha N;

Stage III: 2012 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O; 2013 - 100 kg /ha N; 2014 - 50 kg /ha N;

Stage IV: 2017 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O; 2018 - 100 kg /ha N; 2019 - 50 kg /ha N;

2. Mineral and organic fertilization

Stage I: 1996 - 150 kg /ha N + 50 kg /ha P_2O_5 +50 kg/ha K_2O;
1997 - 100 kg /ha N + 50 kg /ha P_2O_5 + 50 kg/ha K_2O;
1998 - 50 kg /ha N + 50 kg /ha P_2O_5 +50 kg/ha K_2O;

Stage II: 2004 - Sheep night paddocking 5 nights 1 cow/ 6 m^2 + 100 kg /ha P_2O_5;

Stage III: 2011 - cow night paddocking 5 nights 1 cow/ 6 m^2 + 100 kg /ha P_2O_5;

Stage IV: 2017 - cow night paddocking 5 nights 1 cow/ 6 m^2

3. Organic fertilization

Stage I: 1995 - Sheep night paddocking 1 sheep/ 1 m^2 5 nights;

Stage II: 2004 - Sheep night paddocking 1 sheep/ 1 m^2 5 nights + 100 kg /ha P_2O_5;

Stage III: 2011 - cow night paddocking 1 cow/ 6 m^2 5 nights + 100 kg /ha P_2O_5;

Stage IV: 2017 - cow night paddocking 1 cow/ 6 m^2 5 nights.

Factor B: Grass carpet

1. Overseeding 1996, after total weeding (5 liters/ha Glyphosate) 1995 and harrowing (1-2 cm) and rolling;
2. Reseeding in 1996 after total weed control in 1995 and processing with a rolling mill (10-12 cm) before and after sowing;

Factor C: Calcium amendment

1. No amendment;
2. Amendment to 2/3 Ah (approx. 7,5 t/ha CaO)

For overseeding and reseeding, a mixture of perennial grass and leguminous seeds was used, consisting of: *Phleum pratense* Favorit variety (40%), *Festuca pratensis* Transilvan variety (25%), *Lolium perenne* Marta variety (5%), *Trifolium hybridum* - Brașov local population (15%), *Lotus corniculatus* Livada variety (15%), species absent from the spontaneous flora to distinguish the sown grassland from the semi-natural one. It can be observed that in the grass mixture for over-seeding and re-seeding, the grasses *Phleum pratense, Festuca pratensis* and *Lolium perenne* were used, species that do not exist in the spontaneous flora of the subalpine level. After annual floristic surveys in all variants of the experiment, was noted the disappearance of the *Lolium perenne* species from the grass carpet after 5-6 years, *Festuca pratensis* after 8-10 years and the long persistence of the *Phleum pratense* species, after 20 years from sowing, a property that led us to study it more carefully, with a view to creating a variety. 250 clones were taken from the experimental field as initial breeding material, which survived 20 years from the initial *Phleum pratense* seed. In these extreme conditions, it does not reach maturity for seed production, which is why it did not self-seed. The clones were further introduced into the breeding process at Research-Development Institute for Grasslands, Brașov, following the usual mass selection methods, which resulted the new variety “Carpatica”.

RESULTS AND DISCUSSIONS

Following the floristic observations in the first 5 years (1996-2000), it was found that the species *Phleum pratense*, the "Favorit" variety created at the Suceava Agricultural Research Station in 1979, from an initial 40% participation in the mixture, continues to be maintained in a high proportion in the grassy carpet (Table 1).

Table 1

Participation of *Phleum pratense* species in the grassy carpet in the first 5 years after overseeding and reseeding of *Nardus stricta* – degraded subalpine grasslands (Blana-Bucegi 1996-2000)

Fertilization	Overseeding (010)			Reseeding (020)			Difference (%)	
	NA; (001)	A (002)	Average (010)	NA; (001)	A (002)	Average (020)	010 - 020	002-001
Mineral (100)	31.5	53.8	42.7	22.3	52.1	37.7	113	197
Organic (300)	30.8	28.0	29.4	17.3	34.3	25.8	114	129
Average	31.2	40.9	36.1	19.8	43.2	31.5	115	165
Difference (%)100-300	102	192	145	129	152	146	x	x

NA - No amendment; A- amendment

Thus, the highest percentage of the *Phleum pratense* species in the sown mixture of 53.8% was achieved by overseeding (var. 010) on amended soil (002) and mineral fertilization (100). The average effect of overseeding was 15% higher than reseeding and of calcium amendment 65% higher on the participation of the *Phleum pratense* species in the composition of the sown mixture. Mineral fertilization (100) stimulated 45-46% more *Phleum pratense* species than organic fertilization by tillage (300). The main agrochemical factor on which the participation of the *Phleum pratense* species in the grassy carpet depended was the soil reaction after amendment (Table 2).

Table 2

Soil reaction (pH in H2O) after 5 years of calcium amendment and total renovation systems of subalpine degraded grassland by *Nardus stricta* (Blana-Bucegi 2001)

Fertilization	Overseeding (010)			Reseeding (020)			Difference (%)	
	NA; (001)	A (002)	Average (010)	NA (001)	A; (002)	Average (020)	010 - 020	002-001
Mineral (100)	4.75	5.35	5.05	4.70	5.50	5.10	99	115
Organic (300)	4.60	5.50	5.05	4.60	5.20	4.90	103	116
Average	4.68	5.43	5.05	4.65	5.35	5.00	101	115
Difference (%)100-300	103	97	100	102	106	104	x	x

NA - No amendment; A- amendment

In the first 5 years, the amendment (002) raised the soil pH from 4.60 to 5.35-5.50, which contributed to the increase in the participation of the species Phleum pratense by 15%. The highest participation of 52.1-53.8 of the species Phleum pratense was recorded at pH 5.35-5.50 in the amended variants (002) and the lowest of 17.3-19.8 at a pH of 4.6-4.65 in the no amended variants (001), demonstrating the efficiency of calcium amendment for this perennial grass. After 26 years (2018-2022) the participation of the Phleum pratense species in mineral fertilization (100) remains at 25.6% on fined soil (002) after overseeding and 8.4% - respectively 3 times less after reseeding (Table 3).

Table 3

Results regarding the participation of the species *Phleum pratense* in the grassy carpet (%)compared to 40% at sowing after 26 years, depending on the radical improvement method of subalpine grasslands of *Nardus stricta* (after Maruşca T., 2022)

Fertilization	Overseeding (010)			Reseeding (020)			Difference (%)	
	NA; (001)	A (002)	Average (010)	NA; (001)	A (002)	Average (020)	010 - 020	002-001
Mineral (100)	0	25,6	12,8	0	8,4	4,2	305	x
Organo-mineral (200)	16,0	21,2	18,6	9,4	15,0	12,2	152	143
Organic (300)	13,4	16,0	14,7	11,8	17,2	14,5	101	132
Average	9,8	20,9	15,4	7,1	13,6	10,4	148	203
Difference (%)								
100-200	X	83	145	x	170	290	x	x
100-300	X	63	115	x	205	345	x	x
200-300	84	75	79	125	115	119	x	x

NA - No amendment; A- amendment

In the no amended, mineral-fertilized variants, the species *Phleum pratense* disappeared from the grassy carpet in both sowing methods. Under the conditions of organo-mineral fertilization (200) an average participation of *Phleum pratense* was achieved, being from this point of view the best fertilization system. By calcium amendment and mineral fertilization at the beginning the production of green mass per hectare will increase, correspondingly increasing the animal load with which larger areas of grasslands degraded by *Nardus stricta* can be further grazed in more difficult to access areas. After 26 years of applying calcium amendments, it is found that the soil pH is still increasing on average on all agricultural lands (100-300) from 4.9 to 5.37, contributing to this the residual effect of calcium and the favorable effect of animal grazing in the 3-4 rounds (Table 4).

Table 4

Soil reaction (pH) after 20 years of calcium amendment and total renovation systems of subalpine *Nardus stricta* grasslands (Blana-Bucegi 2016)

Fertilization	Overseeding (010)			Reseeding (020)			Difference (%)	
	NA; (001)	A (002)	Average (010)	NA; (001)	A (002)	Average (020)	010 - 020	002-001
Mineral (100)	4.8	5.7	5.25	4.8	5.3	5.05	104	115
Organo-mineral (200)	5.0	5.2	5.10	5.0	5.2	5.10	100	104
Organic (300)	4.9	5.2	5.05	5.0	5.2	5.10	99	105
Average	4.90	5.37	5.14	4.93	5.23	5.08	103	108
Difference (%)								
100-200	104	91	97	104	98	101	x	x
100-300	102	91	96	104	98	101	x	x
200-300	98	100	99	100	100	100	x	x

NA - No amendment; A- amendment

The strongest effect of amendment, pH 5.3-5.7, was observed at variants with mineral fertilization (100) followed by pH 5.2 with organomineral fertilization (200) and the same with organic fertilization (300).

The pH reaction on the overseeded variants is on average 5.14 with 8% higher than on the reseeded variants.

As a first general conclusion, it can be noted that the participation of the *Phleum pratense* species is higher on variant 222 with organomineral fertilization, overseeding and calcium amendment.

The main characteristics of the Carpatica variety, a synthetic variety selected from 8 parental forms from native mountain ecotypes, are: it is a semi-late variety, with good growth and regeneration vigor, very good resistance to diseases such as *Puccinia gr.*, *Erysipha gr.*, *Epichloe typhina*) and good resistance to the timothy fly (*Amaurosoma flavipes*). The growth vigor in spring is good to very good, the regeneration capacity after mowing is good, the behavior in winter conditions is good to very good, the crude protein content is 15.73%, the average dry matter production achieved in the 3 years of testing, in the ISTIS network, is 12.7 t/ha. It can be cultivated from the hilly area, in mixtures for hayfields and grazing up to the subalpine level in the high mountains. (Marusca et all. 2023). It is recommended to use it in complex mixtures, in pre-mountain and mountain areas to improve the permanent or the seeded grasslands.

CONCLUSIONS

1.The *Phleum pratense* species is one of the main perennial grasses, which can improved through total renovation, the degraded *Nardus stricta* grasslands in the high mountains.

2. Long-term experiments in the Bucegi Plateau, on subalpine *Nardus stricta* grasslands located at 1800 m altitude have demonstrated that the species *Phleum pratense,* the Favorit variety with 40% participation in the mixture sown by overseeding, resisted in a proportion of almost 26% on a background amended to 2/3 hectoliter acidity of the soil and adequate organo-mineral fertilization, without self-seeding.

3.The overseeding, calcium amendment and organo-mineral fertilization proved to be superior to reseeding with soil mobilization at 10-12 cm, non-amendment and mineral fertilization, where the species *Phleum pratense* disappeared from the grassy carpet.

4. After 20 years of adaptation to the harsh conditions of frost, sunstroke, drought, in the high mountains, a natural selection of the species occurred, which continued in the classic breeding process at the institute.

5. This new breeding method, in which the initial material is subjected to a longer period of time, to natural selection, in the area where it is to be cultivated, is a guarantee of adaptability and longevity, for future cultivations necessary for the grasslands renovation under climate change conditions.

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PRODUCTIVITY OF THE GRASSLANDS IN THE ARIEȘ VALLEY OF THE APUSENI MOUNTAINS

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Abstract

The grasslands of the Aries Valley are an integral part of the Apuseni Mountains, located between 340 and 1280 m altitude. 153 floristic surveys were carried out, which contained an average of 81 species of cormophytes and an average vegetation cover of 89%, of which 58% were forage species and 31% were species harmful to the grassy carpet. The average pastoral value (PV) of the 18 grassland associations was 39 and the production of green fodder mass (GM) was 7.9 t/ha with an optimal load of 0.7 LU/ha in 170 days of grazing season. In the 5 phytosociological alliances (Cynosurion cristati, Violion caninae, Stipion lessingianae, Festucion rupicolae and Cirsio pannonicae-Brachypodion pinnati) used mainly by grazing, an average of 5 t/ha GM was evaluated, an index of almost 30 VP with which 2900 liters of cow's milk per hectare can be produced with an optimal load of 0.5 LU/ha in a 160-day grazing season. In the alliances harvested in haylage regime (Agrostion albae, Arrhenatherion elatioris and Holco-Juncion) 11.8 t/ha GM and 57.6 PV were evaluated with 236% GM and 193 PV index higher than the grassland alliances used by grazing with animals. Economic data on grassland productivity are used both in the preparation of development projects and in their further management.

Keywords: mountain grasslands, pastoral value, green mass production, milk production, optimal load.

INTRODUCTION

The efficient management of permanent grasslands calls for knowledge of the floristic composition of the grassy carpet, the production and forage quality followed by the means of improvement if they are degraded and further rational use through grazing or mowing (ANGHEL et al., 1967; BĂRBULESCU and MOTCĂ, 1983). These data for evaluating the productivity of grasslands (green mass production and pastoral value) continue to serve for the preparation of their development projects, for establishing the optimal animal load, animal production (milk, meat, etc.) and other economic purposes (MARUȘCA et al., 2014). In this paper, the evaluation of the productivity of mountain grasslands is continued according to the new method based on floristic survey in order to meet the needs presented above.

MATERIAL AND METHOD

In the present work, the floristic surveys from the work "*The grasslands of the Arieș Valley, between Lupșa and Turda*" author Jóseph P. Frink doctoral thesis under the supervision of Prof. Vasile Cristea from the "Babeș-Bolyai" University of Cluj-Napoca were used.

In this work, 18 grassland associations were identified as follows:

Cl. MOLINIO - ARRHENATHERETEA R. Tx. 1937
Ord. MOLINIETALIA Koch 1926
Al. Agrostion albae Soó 1943
1. *As. Agrostio-Deschampsietum caespitosae* Ujvárosi 1947
- *nardosum strictae* (facies cu *Nardus stricta*)
2. *As. Agrostetum albae* Ujvárosi 1941
3. *As. Festucetum pratensis* Soó 1938
Al. Holco-Juncion Pass. 1964
4. *As. Holcetum lanati* Issler 1936 *em.* Pass. 1964
- *caricosum vulpinae* (facies cu *Carex vulpina*)
Ord.ARRHENATHERETALIA Pawlowski 1928
Al. Arrhenatherion elatioris Koch 1926
5. *As. Arrhenatheretum elatioris* Br.-Bl. *Ex* Scherrer 1925
- *trisetetosum flavescentis* Horvatić 1930
6. *As. Trisetetum flavescentis* Rübel 1911
Al. Cynosurion cristati R. Tx. 1947
7. *As. Festuco rubrae-Agrostietum capillaris* Horvat 1951
- *genistetosum sagittalis* Coldea 1991
- *nardosum strictae* (facies *Nardus stricta*)
- *danthoniosum decumbentis* (facies cu *Danthonia decumbens*)
Cl. NARDO - CALLUNETEA Preising. 1949
Ord. NARDETALIA Oberd. *ex* Preising. 1949
Al. Violion caninae Schwickerath 1944
8. *As. Nardo-Callunetum vulgaris* (Šmarda 1953) Csűrös 1964
CL. FESTUCO-BROMETEA Br.-Bl. et R. Tx. ex Klika et Hadač 1944
Ord. FESTUCETALIA VALESIACAE Br.-Bl. et R. Tx. ex Br.-Bl. 1949
Al. Stipion lessingianae Soó 1947
9. *As. Stipetum lessingianae* Soó (1927 n. n.) 1947
- *botriochloosum ischaemi* (facies cu *Dichanthium ischaemum*)
10. *As. Stipetum pulcherrimae* Soó 1942
- *botriochloosum ischaemi* (facies cu *Dichanthium ischaemum*)
Al. Festucion rupicolae Soó 1940 *corr.* 1964

11.As. Stipetum capillatae (Hueck 1931) Krausch 1961
- *botriochloosum ischaemi* (facies cu *Dichanthium ischaemum*)

12. *As. Festuco rupicolae - Caricetum humilis* Soó 1930, 1947
- *botriochloetosum* Raţiu et al. 1969
- *festucosum valesiacae* (facies cu *Festuca valesiaca*)
- *stiposum pulcherrimae* (facies cu *Stipa pulcherrima*)

13. *As. Agrostio - Festucetum rupicolae* Csűrős-Káptalan (1962) 1964
14. *As. Agrostio-Festucetum valesiacae* Borisavljević Jovanović-Dunjić et Mišic 1955
15. As. *Festucetum valesiaco-rupicolae* Csűrös *et* Kovács 1962
- *botriochloosum ischaemi* (facies cu *Dichanthium ischaemum*)

16. *As. Botriochloetum ischaemi Pop 1977*

Ord. BROMETALIA ERECTI Br.-Bl. 1936

Al. Cirsio pannonicae - Brachypodion pinnati Hadač *et* Klika 1944

17. *As. Carici humilis - Brachypodietum pinnati* Soó 1947, 1949
- *festucetosum rupicolae* Kovács *et* Coldea 1967

18. *As. Festuco rupicolae - Brachypodietum pinnati* (Soó 1927) Schneider-Binder 1971

The method for evaluating the production of green fodder mass and pastoral value was done according to the new method based on floristic survey (MARUȘCA, 2019, 2022; MARUȘCA et al. 2021, 2023). Following this method, several works have been published and currently a journal of mountaineering, where more details regarding the working method are presented, on which we will not intervene (MARUȘCA et al. 2020 a, b; MARUȘCA et al. 2023, 2024).

RESULTS AND DISCUSSIONS

In the Arieș Valley between Lupșa and Turda, 18 grassland associations, 8 alliances, 5 orders and 3 vegetation classes were identified between 340-1280 m altitude. (Table 1)

Table 1

Overview of the grassland associations in the Arieș Valley

No.	Association	No. of survey.	Altitude (m)	Exposition	Slope (grade)	Cormophyte (nr)	Coverage %
			Al. ***Agrostion albae***				
1	*Agrostio-Deschampsietum caespitosae*	4	600 (500-620)	PLAN	0	37	80
2	*Agrostetum albae*	4	400 (340-460)	PLAN	0	59	93
3	*Festucetum pratensis*	9	420 (370-450)	PLAN, E, SE	4	106	97
			Al***. Holco-Juncion***				
4	*Holcetum lanati*	3	370	PLAN	0	47	96

No.	Association	No. of survey.	Altitude (m)	Exposition	Slope (grade)	Cormophyte (nr)	Coverage %
			(350-420)				
Al. ***Arrhenatherion elatioris***							
5	*Arrhenatheretum elatioris*	23	420 (350-580)	PLAN, W, E, S, SE, NE	3	161	98
6	*Trisetetum flavescentis*	2	400 (380-420)	E	4	46	100
Al. ***Cynosurion cristati***							
7	*Festuco rubrae-Agrostetum capillaris*	41	730 (450-1280)	N, S, NW, SE, W, NE, E, PLAN	12	186	98
Al. ***Violion caninae***							
8	*Nardo-Callunetum vulgaris*	4	740 (650-1000)	S	12	42	88
Al. ***Stipion lessingianae***							
9	*Stipetum lessingianae*	5	420 (400-450)	SW, S	34	34	79
10	*Stipetum pulcherrimae*	5	400 (350-490)	S, SW	19	61	68
Al**. *Festucion rupicolae***							
11	*Stipetum capillatae*	6	400 (350-400)	S, SE	16	72	65
12	*Festuco rupicolae-Caricetum humilis*	8	480 (400-640)	S, W, E	17	108	85
13	*Agrostio-Festucetum rupicolae*	7	580 (390-680)	W, S, E, SE, SW, P	9	90	95
14	*Agrostio-Festucetum valesiacae*	7	620 (550-850)	S, SW, E, SE	22	95	96
15	*Festucetum valesiaco-rupicolae*	9	460 (360-580)	PLAN, S, SW, E, SE	4	113	90
16	*Botriochloetum ischaemi*	4	370 (350-420)	S, SE	14	39	86
Al. ***Cirsio pannonicae-Brachypodion pinnati***							
17	*Carici humilis-Brachypodietum pinnati*	4	660 (450-900)	W, S	12	80	92
18	*Festuco rupicolae-Brachypodietum pinnati*	8	500 (350-550)	N, E, NW, PLAN, W	6	90	87
AVERAGE-TOTAL		**153**	**470 (340-1280)**	**ALL**	**10**	**81**	**89**

In the 153 surveys conducted with an average vegetation cover of 89%, 81 species of cormophytes were determined. The associations with the most cormophyte species were *Festuco rubrae-Agrostetum capillaris (*186 species), *Festucetum valesiaco-rupicolae* (113 species), *Festuco rupicolae - Caricetum humilis* (108 species) and *Festucetum pratensis* (106 species) and the lowest number of species was recorded in *Stipetum lessingianae* (34 species), *Agrostio-Deschampsietum caespitosae* (37 species) and *Botriochloetum* *ischaemi* (39 species). The average participation in the grassy carpet was 58% species with forage value and 31% harmful species, a ratio that influenced the pastoral value index (PV) which was 39.22 (mediocre), the green mass production (GM) of 7.88 t/ha, with an optimal load of 0.68 LU/ha in 170 days of grazing season (Table 2).

Table 2

Forage structure, pastoral value, green mass production and optimal animal loading

No.	Association	Species structure (%)		Pastoral value		Green mass production (t/ha)	Grazing season duration (days)	Animal loading (LU/ha)
		Forager	Harmful	Ind.	%			
Al. ***Agrostion albae***								
1	*Agrostio-Deschampsietum caespitosae*	28	52	18.86	48	2.44	170	0.22
2	*Agrostetum albae*	75	18	61.22	156	12.56	160	1.21
3	*Festucetum pratensis*	89	8	74.89	191	14.95	165	1.39
Al**. *Holco-Juncion***								
4	*Holcetum lanati*	68	28	45.78	117	9.50	155	0.94
Al. ***Arrhenatherion elatioris***								
5	*Arrhenatheretum elatioris*	91	7	76.79	196	18.46	165	1.72
6	*Trisetetum flavescentis*	93	7	73.87	188	13.57	160	1.30
Al. . ***Cynosurion cristati***								
7	*Festuco rubrae-Agrostetum capillaris*	81	17	56.84	145	9.02	155	0.90
Al. . ***Violion caninae***								
8	*Nardo-Callunetum vulgaris*	20	68	13.49	34	1.46	155	0.14
Al. ***Stipion lessingianae***								
9	*Stipetum lessingianae*	16	63	7.66	20	0.59	165	0.05
10	*Stipetum pulcherrimae*	16	52	8.00	20	0.77	160	0.07
Al**. *Festucion rupicolae***								
11	*Stipetum capillatae*	3	62	1.98	5	0.27	160	0.03
12	*Festuco rupicolae-Caricetum humilis*	60	25	36.06	92	5.45	170	0.49
13	*Agrostio-Festucetum rupicolae*	82	13	54.08	138	8.94	165	0.83
14	*Agrostio-Festucetum valesiacae*	69	27	43.88	112	6.00	160	0.58
15	*Festucetum valesiaco-rupicolae*	77	13	44.16	113	7.87	170	0.71
16	*Botriochloetum ischaemi*	16	70	8.38	21	1.12	155	0.11
Al. ***Cirsio pannonicae-Brachypodion pinnati***								
17	*Carici humilis-Brachypodietum pinnati*	71	21	38.03	97	6.52	165	0.61
18	*Festuco rupicolae-Brachypodietum pinnati*	74	13	42.02	107	11.35	175	1.0
AVERAGE		**57**	**31**	**39.22**	**100**	**7.82**	**170**	**0.68**

The highest productivity was evaluated in associations harvested mainly in hay regime such as *Arrhenatheretum elatioris* (76.79 PV; 18.46 t/ha GM), *Festucetum pratensis* (74.89 PV; 14.95 t/ha

GM) and *Trisetetum flavescentis* (73.87 PV; 13.57 t/ha GM). The lowest productivity was evaluated in associations dominated by *Stipa sp.* (2-8 PV; 0.3-0.8 t/ha GM) associations with degraded forage vegetation *Botriochloetum ischaemi* and *Nardo-Callunetum vulgaris* (8-13.5 PV; 1.12-1.46 t/ha GM) valorized by grazing with animals at a load of only 0.03-0.14 LU/ha. The phytosociological alliance level analysis with data closer to Natura 2000 habitats is presented in Table 3.

Table 3

Grazing season duration, pastoral value, green mass production and cow's milk at grassland phytosociological alliance level

Phytosociological alliance		Grazing season duration (days)	Green mass production		Animal loading LU/ha	Pastoral value (ind.)	Milk production	
			t/ha	%			L/ha	%
A. Pasture, main use								
Cynosurion cristati		155	9.02	180	0.90	56.8	5280	182
Violion caninae		155	1.46	29	0.14	13.5	1260	43
Stipion lessingianae		165	0.68	14	0.06	7.8	770	27
Festucion rupicolae		165	4.94	99	0.46	31.4	3110	107
Cirsio pannonicae-Brachypodion pinnati		170	8.93	178	0.81	40.0	4080	141
Average A		**160**	**5.01**	**100**	**0.47**	**29.9**	**2900**	**100**
B. Hay, main use								
Agrostion albae		x	9.98	84	x	51.7	x	x
Holco-Juncion		x	9.50	80	x	45.8	x	x
Arrhenatherion elatioris		x	16.01	135	x	75.3	x	x
Average B		x	**11.83**	**100**	**x**	**57.6**	x	x
Difference B-A	+,-	x	**+6.82**	x	x	**+27.7**	x	x
	%	x	**236**	x	x	**193**	x	x

By synthesizing the 18 grassland associations in 8 phytosociological alliances similar to EU habitats (GAFTA, MAOUNTFORD, 2008), the average productivity results are slightly different from those evaluated at the level of component associations. The equivalent of cow's milk production is a final parameter for evaluating the productivity of a grassland, which in our case varied within very wide limits depending on the pastoral value and the duration of the grazing season dependent on altitude and air temperature (MARUȘCA, 2022). Thus, in the grasslands used by grazing with animals at the level of the 5 phytosociological alliances, 5t/ha green mass (GM) was evaluated, a pastoral value (PV) of almost 30, 2900 liters of cow's milk per hectare can be produced with a load of almost 0.5 LU /ha in an average season of 160 days grazing season. The most valuable alliance is *Cynosurion cristati* with 9 t/ha GM, PV index of 57, 5280 L/ha milk in

155 days of grazing with a load of 0.9 LU/ha. The worst results were evaluated in the alliance *Stipion lessingianae* with 0.7 t/ha GM, PV index of 7.8, 770 L/ha milk in 165 days of grazing with a load of 0.06 LU /ha. Poor results were also evaluated in one of the most widespread alliances *Violion caninae* which has its origin in *Cynosurion cristati* through its invasion by the species *Nardus stricta*, where 1.46 t/ha GM is obtained, a PV index of only 13.5 and 1260 L/ha milk, achieved in 155 days of grazing with a load of 0.14 LU /ha. The last 3 alliances mainly exploited as hay achieve an average production of 11.8 t/ha GM and a 57.6 PV index with 236% GM and 193% PV index higher than the average of alliances exploited by grazing. The highest GM production and PV index were evaluated in the *Arrhenatherion elatioris* alliance (16t/ha GM and 75 PV) and the lowest in *Holco-Juncion* (9.5t/ha GM and 46 PV). Grasslands used by mowing for hay are better managed and fertilized than those used by grazing with animals.

CONCLUSIONS

The permanent grasslands of the Arieș Valley located between 340-1280 m altitude with a remarkable phytodiversity represented by 372 species of cormophytes, 18 associations, 8 alliances and 5 orders belonging to 3 vegetation classes.The association with the most species was *Festuco rubrae-Agrostetum capillaris* (186 species) and the fewest at *Stipetum lessingianae* (34 species). The best productivity was evaluated at the *Arrhenatheretum elatioris* association with a pastoral value (PV) of 76.8 and a green fodder mass production (GM) of 18.5 t/ha. The lowest productivity was evaluated at the *Botriochloetum ischaemi* and *Nardo-Callunetum vulgaris* associations with 8-13.5 PV and 1.12-1.46 t/ha GM. At the phytosociological alliance (habitat) level, the most valuable was *Cynosurion cristati* with 9 t/ha GM, 57 PV index, 5280 liters of milk per hectare in 155 days of grazing season, and the weakest was evaluated at *Stipion lessingianae* with 0.7 t/ha GM, 7.8 PV index, 770 L/ha milk in 165 days of grazing season.

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STUDIES ON THE HEAVY METAL BIOREMEDIATION ABILITY OF MULTIPLE SPECIES – A CASE STUDY ON BAIA MARE SITES

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Abstract
Bioremediation is a sustainable method for restoring the quality of soil in urban areas affected by heavy metal contamination. Plant samples were analyzed using portable X-ray fluorescence spectrometry (pXRF) to determine the concentrations of heavy metals accumulated in the studied species. Analysis of the accumulation capacity of heavy metals in various sites revealed significant differences between the plant species investigated. Species such as Lavandula angustifolia, Salix viminalis, Salix alba and Agrostis capillaris showed high levels of bioaccumulation for certain metals, highlighting a specific and differentiated potential for application in phytoremediation processes. These results highlight the need for a rigorous selection of plant species used in phytoremediation, correlated with the predominant type of heavy metal, in order to optimize the efficiency of ecological remediation processes.

Keywords: *polluted soils, heavy metals, phytoextraction, bioremediation, Agrostis capillaris*

INTRODUCTION

Heavy metals are a type of pollutant commonly encountered, and due to their high toxicity, soil contamination with these substances can represent a significant risk to soil organisms, including microbial communities (Zhao et al., 2019).

Soil pollutants mainly originate from human activities and include biological, domestic and industrial residues, improperly stored waste or manure, all of which have a negative impact on soil metabolism. Industrial metal mining and processing activities constitute a significant source of heavy metal contamination of agricultural soils (Navarro et al., 2008).

In the context of increasing soil degradation caused by heavy metal pollution resulting from anthropogenic activities, researchers' interest in soil microbial imbalances is growing. Soil acts as an important reservoir for numerous contaminants (Sandu et al., 2018).

Soil is a complex environment, consisting of a solid, a liquid and a gaseous phase, the components of which undergo significant variations. The interaction between this soil system and the plants that grow in it forms what is known as the soil-plant ecosystem (Chen et al., 2010; Corcoz et al., 2022; Păcurar et al., 2020; Sângeorzan et al., 2024; Wu et al., 2011).

Soil degradation means the reduction or loss of its functions and uses. Soil performs three ecological functions: it produces biomass (food, feed, raw materials), filters and transforms substances between the atmosphere, water and vegetation, and provides biological habitat (Sandor et al., 2016; Stoian et al., 2022; Vidican and Sandor, 2015). At the same time, it has technical, industrial and socio-economic functions, serving as support for constructions, a source of resources and an element of heritage that protects archaeological and natural values (Blum et al., 1998; Gaga et al, 2022; Onica et al., 2017; Rotar et al., 2020; Vaida et al., 2021).

When heavy metals reach the soil, they undergo transformations into various geochemical forms because of physical, chemical and biological processes, such as adsorption, dissolution, complexation and absorption by organisms (Liu et al., 2013).

The toxicity and bioavailability of heavy metals in soil are influenced not only by their total concentration, but also by the form in which they are found. For example, water-soluble forms and those associated with carbonate are considered the most readily available to organisms; reducible forms, bound to Fe/Mn oxides, and oxidizable forms, associated with organic matter, can become bioavailable under certain conditions, while the residual fraction, fixed in the soil matrix, is not accessible to plants (Delgado și colab., 2011; Rodríguez și colab., 2009). In this context, understanding the concentration of labile fractions of heavy metals is particularly important (Liu wt al., 2013).

The chemical forms in which heavy metals are found in soil significantly influence their mobility. Cadmium (Cd), zinc (Zn) and molybdenum (Mo) are among the most mobile elements, while chromium (Cr), nickel (Ni) and lead (Pb) have considerably lower mobility. (Fijałkowski et al., 2012).

Given the current need for green spaces in urban landscapes, the value of brownfields as potential recreational space is increasingly widely recognized (Merwin et al., 2022).

Regarding the remediation of soils contaminated with heavy metals (HM), several methods are currently available. Among them, phytoremediation is considered the most environmentally friendly and cost-effective technology. This emerging method is based on the ability of certain green plants to extract heavy metals from contaminated soils (Angelova et al., 2015; Carabulea et al., 2022).

Phytoremediation is the process by which plants are introduced into the environment to promote the assimilation of contaminants in their roots and leaves. Although this process has been recognized and demonstrated by humans for more than 300 years, scientific studies on phytoremediation only began after the 1980s (Lasat, 2000).

Phytostabilization consists of reducing the mobility and bioavailability of soil contaminants, through physical or chemical mechanisms, with the aim of preventing their spread in the environment. (Vidican et al., 2023). Phytodegradation, a method applicable especially to organic compounds, involves the decomposition or transformation of contaminants into less toxic forms, through the release of enzymes at the root level or through metabolic activities carried out inside plant tissues. (Vidican et al., 2023).

In phytovolatilization, contaminants are absorbed by plant roots, transformed into gaseous compounds and subsequently released into the atmosphere through the foliar system, through the process of evapotranspiration (Laghlim et al., 2015).

Phytoextraction refers to the accumulation of contaminants in the aboveground (harvestable) biomass of plants, either through a continuous natural process using hyperaccumulator plants or through an induced process using chelating agents. Hyperaccumulator plants are adapted to soils with naturally high metal content and have the ability to efficiently accumulate various metals in their tissues (Vâtcă et al., 2022; Vidican et al., 2023).

The main aim of this research is to assess the level of heavy metal pollution in relation to a set of plants, from the Baia Mare area, a region known for its industrial and mining activities, which have had a significant impact on soil quality.

MATERIAL AND METHOD

The research methodology, including the techniques for collecting, processing and analyzing field data, is consistent with the established objectives. In Baia Mare, we proposed to use phytoextraction as the first method, and phytostabilization as the secondary method, given that the plants were selected based on their phytoextraction potential.

In accordance with the established objectives, based on the favorability and soil indices, the species identified with phytoremediation potential in Baia Mare, according to SPIRE-UIA-138, are the following: *Agrostic capillaris, Calamagrostis epigeos,* *Myschantus giganteus, Reynoutria japonica, Salix alba-existent, Salix alba nou, Salix viminalis, Fraximus excelsor,Iris germanica, Lavandula angustifolia, Pinus nigra, Robinia pseudoacacia, Betula pendula – existent, Parthenocissus quinquefolia, Salix viminalis nou, Acer platanoides, Amorpha fructicosa, Sorbus aucuparia, Catalpa bignonioides globose, Equisetum arvense, Juniperus spp., Prunus laurocerasus, Sorbus aucuparia.*

These species were selected based on preference criteria for ecological zoning, considering their phytoremediation capacity and other uses. The natural distribution area was assessed to verify whether these species exist in the spontaneous flora, either as species or varieties, and whether they meet the necessary edaphic and thermal conditions throughout the experimental vegetation cycle (including the sum of temperature degrees). The average amount of precipitation was also taken into account to ensure their adaptability to the local environment.

Samples were taken from 5 different sites, namely: Craica, Colonia Topitorilor, RombPlumb, Ferneziu and Urbis in the city of Baia Mare (47°39′ N, 23°34′ E), located in northwestern Romania, on a total area of 7.3 hectares of brown soils. These locations present different levels of heavy metal contamination, mainly originating from anthropogenic activities such as mining, metallurgy and urban expansion. After taking plant samples from the five experimental sites, they were dried under ambient conditions, then ground using a Grindomix Retsch GM 200 knife mill. Finally, the samples were analyzed by portable X-ray fluorescence spectrometry (pXRF) to determine the heavy metals accumulated in the analyzed plant species.

RESULTS AND DISCUSSIONS

The way in which heavy metals can accumulate in plant and animal organisms, including humans, as well as the pathology they cause, justify the interest given to these pollutants. The lack of monitoring and control of heavy metals in soils, air and water can represent a major danger to the environment and, in particular, to human health.

Metals, natural components of soil, are classified according to their physiological role into essential heavy metals (such as Fe, Mn, Cu, Zn and Ni), which act as indispensable micronutrients for the physiological and biochemical processes of plants. These are taken up from the soil solution and included in the structure of enzymes and proteins, and non-essential metals (such as Cd, Pb, As, Hg and

Cr), which have no known biological role, but regardless of their type, high concentrations of heavy metals can inhibit plant growth and induce symptoms of toxicity, however, certain plant species can survive and even develop in contaminated soils, such as those in the vicinity of mining operations (Laghlini et al., 2015).

Following the analysis of plant species from the sites contaminated with heavy metals, it was found that certain species have a superior capacity to extract heavy metals, while others have a reduced capacity, and for some species the concentrations of heavy metals were below the detection limit. These results vary depending on the plant species present on the five experimental sites.

The study aimed to identify and analyze the potential for ecological rehabilitation of contaminated soils by applying the phytoremediation technique – a process that involves the use of plants capable of absorbing, accumulating or stabilizing heavy metals in the soil. In this regard, several plant species from the affected lands were analyzed. The species were chosen based on their tolerance and efficiency in extracting or immobilizing metals, and the efficiency of each species will be monitored and compared to determine the most promising solutions for ecological remediation of these degraded soils.

The chosen species must demonstrate the ability to extract heavy metals from the soil through the root system and the foliar apparatus, while it must be able to be subsequently exploited.

Plant species from the Craica site varied significantly in their capacity to accumulate heavy metals (table 1). *Agrostis capillaris* proved to be the most efficient species for Pb extraction, followed by Myschantus giganteus and *Salix alba* new. Salix alba – extant had the lowest extraction value.

Table 1

Plant species and their capacity to extract heavy metals from the Craica site

Species	**Pb**	**Cu**	**Cd**	**Zn**
Agrostis capillaris	82.25	66.63	11.13	464.50
Calamagrostis epigeos	4.75	43.25	4.50	98.00
Myschantus giganteus	65.06	42.75	23.31	141.69
Reynoutria japonica	35.63	43.00	17.25	328.00
Salix alba- present	2.50	49.25	20.13	524.88
Salix alba new	60.00	54.13	23.13	830.13
Salix viminalis	36.63	22.63	8.13	131.25

For copper (Cu) extraction, *Agrostis capillaris* had the highest value (66.63 mg/kg), followed by *Salix alba* new and *Salix alba* – present. *Salix viminalis* recorded the lowest value (22.63 mg/kg). In the case of cadmium (Cd), *Myschantus giganteus* (23.31 mg/kg) and *Salix alba new* (23.13 mg/kg) were the most efficient, followed by *Salix alba – present*, and *Calamagrostis epigeos* had the lowest extraction capacity (4.50 mg/kg). *Salix alba new* has an exceptional Zn accumulation capacity (830.13 mg/kg), followed by *Salix alba – present* and *Agrostis capillaris*. *Calamagrostis epigeos* had the lowest value (98.00 mg/kg).

After analyzing the extraction capacity of heavy metals in the Colonia Topitorilor site (table 2), it was highlighted that the plant species Agrostis capillaris had the highest value in lead extraction (84.00 mg/kg). *Robinia pseudoacacia* recorded the highest values for copper extraction (51.88 mg/kg), and *Fraxinus excelsior* stood out for its highest cadmium extraction capacity (21.08 mg/kg). Salix viminalis showed a very high phytoextraction capacity of Zn (792.50 mg/kg) in this site.

Table 2

Plant species and their capacity to extract heavy metals from the Colonia Topitorilor site

Species	Pb	Cu	Cd	Zn
Agrostis capillaris	84		2.75	38
Fraxinus excelsior		25.33	21.08	61.04
Iris germanica	14.75	38.00	16.00	69
Lavandula angustifolia		47.63	18.50	83.63
Pinus nigra		47		104.50
Robinia pseudoacacia	4.25	51.88	20.70	79.88
Reynoutria japonica		42.67	17.33	214.58
Salix alba - new	11.33	50.29	19.50	564.42
Salix viminalis	11.50	36.50	18.00	792.50

In the analysis of the capacity of plant species to extract heavy metals in the Ferneziu site (table 3), it is observed that *Salix alba* (both existing and new) stands out as the most efficient species for the accumulation of lead (Pb), copper (Cu), cadmium (Cd) and zinc (Zn), especially the existing *Salix alba*, which accumulated exceptional amounts of zinc. Also, *Reynoutria japonica* proves efficient in extracting Pb and Cu, while *Salix viminalis* is well-placed for the accumulation of Cu and Zn. Species from the genera *Betula pendula* and *Parthenocissus quinquefolia* are less efficient, with low values for most metals, especially for cadmium and zinc.

In the Romplumb site (table 4), *Sorbus aucuparia* is the most efficient species for lead accumulation (23.50 mg/kg), while *Agrostis capillaris* has the lowest HM extraction (4.25 mg/kg). Regarding copper, *Salix alba - new* shows an exceptional accumulation capacity (60.88 mg/kg), and *Agrostis capillaris* records the lowest value (15.50 mg/kg). For cadmium extraction, *Salix alba - new* is the most efficient species (23.50 mg/kg), compared to *Reynoutria japonica*, which accumulates only 14.75 mg/kg. There is a significant difference regarding zinc accumulation, *Betula pendula* which has a very high accumulation capacity (1057.75 mg/kg), and *Agrostis capillaris* which accumulates only 33.25 mg/kg.

Table 3

Plant species and their capacity to extract heavy metals from the Ferneziu site

Species	Pb	Cu	Cd	Zn
Agrostis capillaris	20.75	37.50	16.75	647.50
Betula pendula -existent	15.75	46.75	23.25	272.25
Betula pendula -nou	34.75	46.79	14.38	337.04
Myschanthus giganteus		43.13	14.92	88.54
Parthenocissus quinquefolia	7.08	39.75	20.04	111.75
Reynoutria japonica	36.30	54.93	19.43	330.93
Salix alba - present		55.25	28.50	1963.75
Salix alba - new	57.75	64.00	22.25	839.63
Salix viminalis nou	14.83	54.25	21.91	817.25

Table 4

Plant species and their capacity to extract heavy metals from the Romplumb site

Species	Pb	Cu	Cd	Zn
Acer platanoides -nou	13.88	44.50	20.38	101.50
Agrostis capillaris	4.25	15.50		33.25
Amorpha fructicosa			10.50	72.25
Betula pendula	15.50	45.63	22.95	1057.75
Reynoutria japonica	13.75	47.875	14.75	568.38
Robinia pseudoacacia	11.63	44.75	17.63	99.88
Salix alba - present	7.00	34.13	20.13	898.75
Salix alba - new	11.75	60.88	23.50	897.13
Salix viminlis nou	15.38	33.00	19.88	624
Sorbus aucuparia	23.50	47.58	13.08	115.50

In the Urbis site (table 5), *Lavandula angustifolia* presents the highest lead accumulation capacity (127.88 mg/kg), followed by

Equisetum arvense (28.25mg/kg). This significantly exceeds the values of Juniperus spp., *Sorbus aucuparea* and *Salix viminalis* species which represent low accumulations < 8 mg/kg. *Lavandula angustifolia* differs by a significantly higher concentration of Cu (90.75), almost double that of Juniperus spp. (54.46). *Agrostis capillaris* records the lowest value, of 19.50. *Salix species*, such as *Salix alba* and *Salix viminalis*, are located in the area of average values, between 31.19 and 40.17.

The highest Cd value was recorded in *Salix viminalis* (43.83), followed by *Juniperus spp*. (20.13) and Equisetum arvense (19.63), these being the species with the highest capacity to accumulate this metal. In contrast, the lowest values were observed in *Agrostis capillaris* (7.00), *Lavandula angustifolia* (15.13) and *Catalpa bignonioides* globosa (16.13), indicating a lower capacity to accumulate cadmium.

Salix viminalis presented the highest extraction of Zn (498.83), followed by *Salix alba* (381.06), *Equisetum arvense* (352.88) and *Reynoutria japonica* (292.75). The lowest values were recorded in *Juniperus spp*. (65.21), *Prunus laurocerasus* (70.13) and *Catalpa bignonioides globosa* (111.63), which present a significantly lower capacity to absorb zinc.

Table 5

Plant species and their capacity to extract heavy metals from the Urbis site

Species	**Pb**	**Cu**	**Cd**	**Zn**
Agrostis capillaris		19.50	7.00	125.25
Catalpa bignonioides globosa		45.25	16.13	111.63
Equisetum arvense	28.25	51.63	19.63	352.88
Juniperus spp.	7.46	54.46	20.13	65.21
Lavandula angustifolia	127.88	90.75	15.13	270.50
Prunus laurocerasus		29.25	15.25	70.13
Reynoutria japonica		26.58	17.42	292.75
Salix viminalis	2.75	40.17	43.83	498.83
Salix alba - present		31.19	17.19	381.06
Salix alba new		37.83	19.17	162.17
Sorbus aucuparia	4.00	44.25	15.50	109.25

The analysis of the bioaccumulation capacity of heavy metals in different sites revealed significant variations among the plant species studied. Species such as *Lavandula angustifolia*, *Salix viminalis*, *Salix alba* and *Agrostis capillaris* were highlighted by high accumulations for specific metals, indicating a differentiated and selective potential in phytoremediation. These differences suggest the need for an adapted selection of species depending on the type of contaminant present, in order to optimize the efficiency of phytoremediation processes.

Identifying the most suitable candidate plant species represents an essential challenge in the application of phytoremediation, given the risk that hazardous heavy metals (HM) enter human and animal organisms through food chains (Gupta et al., 2013).

Phytoextraction is based on the use of natural hyperaccumulator plants, which have an exceptional capacity to accumulate metals. Hyperaccumulators are plant species capable of accumulating metals at levels up to 100 times higher than those obtained by common non-accumulating plants.

CONCLUSIONS

In the Craica site, the most efficient species in bioaccumulating heavy metals were *Salix alba*, *Agrostis capillaris* and *Myschantus giganteus*, which presented consistently high values for two or more of the analyzed contaminants.

In the Colonia Topitorilor site, *Agrostis capillaris* accumulated the most Pb, *Robinia pseudoacacia* – Cu, *Fraxinus excelsior* – Cd, and *Salix viminalis* presented the highest phytoextraction capacity of Zn, highlighting the selective potential of the species for phytoremediation.

In the Ferneziu site, *Salix alba* (existing and new) proved to be the most efficient species in accumulating Pb, Cu, Cd and Zn, especially the existing variant for zinc. *Reynoutria japonica* was efficient in extracting Pb and Cu, and *Salix viminalis* significantly accumulated Cu and Zn.

At the Romplumb site, *Sorbus aucuparia* stood out as the most efficient species for lead accumulation, and *Salix alba* presented the highest values for copper and cadmium.

At the Urbis site, *Lavandula angustifolia* stood out for its exceptional capacity for lead and copper accumulation, significantly surpassing other species. *Salix viminalis* accumulated the highest levels of cadmium and zinc, along with *Salix alba* and *Equisetum arvense.*

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STUDIES ON THE ECONOMIC EVALUATION OF THE PRODUCTIVITY OF AGROSILVOPASTORAL SYSTEMS WITH DOWNY OAK (*QUERCUS PUBESCENS*) IN DOBROGEA

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Abstract

One of the most effective measures to prevent the negative impact of global warming on grasslands is the agrosilvopastoral system (ASP), in which trees have a favorable impact on the grass cover, production and livestock welfare throughout the entire grazing season. On studied grassland with 75 downy oak (Quercus pubescens) trees per hectare in Northern Dobrogea, a 145-day grazing season yields a production of 2,400 liters of cow's milk per hectare, 23% more than on treeless pastures, where the yield was estimated at 1,850 l/ha. Additionally, in the ASP system, the harvesting of wood after 120 years produces 28 m³ of construction timber and 5.5 m³ of firewood per hectare. The average annual acorn production is approximately 75 kg/ha/year. The annual economic value, expressed in euros, of ASP systems with downy oak is €1,375, consisting of €1,200 from milk (87%), €135 (10%) from acorn, and €40 (3%) from timber and firewood, which is 33% higher than the value of milk from treeless pasture, which is €925 (100%). Beyond these higher values, ASP systems offer additional benefits compared to treeless pastures, such as improved livestock welfare, biodiversity conservation, carbon storage, landscape value, and other ecosystem services that are harder to quantify financially.

Keywords: agrosilvopastoral systems, *Quercus pubescens*, production and value of milk, wood and acorns

INTRODUCTION

Global climate warming requires the implementation of preventive measures to mitigate its negative effects, similar to those adopted in countries with hot and dry climates. Among the most widespread of these are agrosilvopastoral systems (ASP), also known as "dehesa," "montado," or "agroforestry" systems (OLEA and SAN MIGUEL, 2006; SHARROW and FLECHTER, 1994). In Romania, these grasslands with scattered trees are traditionally referred to as "rariște" or "dumbravă." They are commonly found on communal pastures and grazing lands in warmer, drier regions, where they provide shade for animals during the grazing season (MIHĂILĂ et al., 2010; MARUȘCA, 2012). These ASP systems in our country have been less studied in the past; however, recent climate changes have raised the need to investigate ASP systems in various regions of Romania, resulting in a first synthesis presented by MARUȘCA et al. in 2020. In these studies, based on floristic surveys from grasslands without trees and those with tree canopy cover, the production of green forage mass and pastoral value were assessed, highlighting the role of woody vegetation in protecting pastures and livestock from excessive heat (MARUȘCA, 2019; 2022). This paper presents a comprehensive economic evaluation of an agrosilvopastoral (ASP) system with downy oak (*Quercus pubescens*) in the Dobrogea region, focusing on the production of milk, construction wood, firewood, and acorns, At national level Dobrogea is one of the regions most affected by global warming.

MATERIAL AND METHOD

The study on the agrosilvopastoral (ASP) system with downy oak (*Quercus pubescens*) was conducted on the pasture near the village of General Praporgescu, Cerna commune, Tulcea County, located in the northern part of the Dobrogean Plateau.

The production of green forage and its pastoral value were evaluated using a new method based on floristic surveys taken in open fields and under tree crowns, proposed by MARUȘCA (2019).

Green fodder production and its pastoral value were evaluated using a new method based on floristic surveys taken in the open field and under tree crowns proposed by MARUȘCA, 2019.

The cow milk production per hectare was estimated using the following formula:

Milk prod. (l/ha) = PV × GSD × 0.6

where:

- PV = pastoral value index
- GSD = grazing season duration (in days)
- 0.6 = forage-to-milk conversion coefficient (MARUȘCA et al., 2018)

The assessment of the number of trees, component species, volume of timber and firewood, and fruit (acorn) production was carried out in three plots, each measuring 10,000 m² (Fig. 1).

The volume of the trees was calculated using formulas that take into account the trunk diameter and the height of the tree. The most commonly used general formula for calculating tree volume is:

$V = BA \cdot h \cdot f = 0.7854 \cdot DBH^2 \cdot h \cdot f$ (GIURGIU, 1979)

MARUȘCA

- V = tree volume (m³)
- BA = basal area (m²)
- DBH = diameter at breast height (cm)
- h = total tree height (m)

Fig. 1. General Praporgescu Pasture and the location of the experimental plots,

- f = form factor, accounting for trunk shape (typically ranging from 0.4 to 0.7 for forest trees). Given that the trees present in pastures are generally old and grow in isolation, without competition, with wide crowns and thick trunks, their shape no longer conforms to the cylindrical form typical of forest-grown trees. Therefore, the value of the form factor, *f*, was empirically adjusted accordingly, being lower and ranging between 0.35 and 0.40. As a result, volume estimates may have a margin of error, caused by the lack of precise field data on the volume of isolated trees on the grassland. It should also be noted that the volume calculated using this formula includes only the trunk volume, from the base up to the top of the main stem and does not account for thick and secondary branches. To include the volume of branches, an additional correction factor is applied, which for broadleaf species ranges from 0.30 % to 45 % of the trunk volume. For the experimental plots located on the General Praporgescu pasture, the trunk volume of the trees was determined by applying the previously presented formula, using a form factor value of f = 0.35, as the tree trunks were often irregular in shape (twisted, leaning) and showed various defects.

RESULTS AND DISCUSSIONS

The economic evaluation of the ASP system with downy oak was carried out based on the green biomass production and pastoral value obtained from the treeless pasture and the pasture under tree canopy (Table 1).

Table 1

Evaluation of the main grassland productivity indicators in the ASP system with downy oak during a 145-day grazing season

Specification	Unit	Open grassland	Under trees	Difference (%)
Green forage mass production	t/ha	1.90	4.14	218
Optimal livestock load	LU/ha	0.20	0.44	220
Pastoral value	Ind.	21.3	36.6	172
Cow milk production	L/ha	1850	3180	172

These data show that the herbaceous vegetation under tree crown is 172–218% higher compared to the open pasture without shade. In the three 10,000 m² plots, the structure and main characteristics of the pasture trees were studied (Table 2). The trunk volume of 218 downy oak trees (*Quercus pubescens*) recorded across a 3-hectare inventory plot with diameters ranging from 8 to 56 cm and heights from 3.1 to 13.5 meters is 65 m³. This corresponds to an average of 21.67 m³/ha, based on a density of 73 trees per hectare. Additionally, for the seven isolated oriental hornbeam (*Carpinus orientalis*) trees located on the pasture (with diameters between 13 and 29 cm and heights from 7.1 to 10.5 m), the cumulative trunk volume is 1.1 m³. In the case of oriental hornbeam, the estimated volume of the two trees recorded per hectare is 0.37 m³. These figures refer strictly to the trunk volume, measured from the base to the top of the main stem. Downy oak exhibits slow growth and generally develops poorly formed trunks, which makes it unsuitable for use in construction or the furniture industry. As a result, its wood is considered usable exclusively as firewood. Similarly, oriental hornbeam is used exclusively as firewood, as its deformed trunk makes it unsuitable for other purposes, such as timber production.

Table 2

The main dendrometric parameters of the trees on the General Praporgescu pasture

Parameters	ST P	CĂ	MJ	Total
Number of trees	217	7	1	225
Mean DBH (cm)	30	22	33	
Min	8	13		
Max	56	29		
Coefficient of variation (%)	33	26		
Mean H (m)	9,0	9,0	7,1	
Min	3,1	7		
Max	13,5	11		
Coefficient of variation (%)	19	14		
Mean crown H (m)	6,7	6,7	4,9	
Min	1,4	4,9		
Max	9,9	8,3		

Parameters	ST P	CĂ	MJ	Total
Coefficient of variation (%)	24	22		
Crown ratio (%)	74	75	69	
Min	36	65		
Max	85	85		
Coefficient of variation (%)	9	10		
Mean crown projection area (m²)	58,0	48		
Min	9,5	28		
Max	149,0	66		
Coefficient of variation (%)	49	30		
Σ S crown projection / ha (m²)	3987	145		

Symbols: ST P – *Quercus Pubescens*, CĂ – *Carpinus orientalis*MJ – *Fraxinus ornus*, Mean DBH – Mean diameter at the breast height; Mean H – Mean height; Min – Minimum recorded value, Max – Maximum recorded value, Crown ratio (%) of total tree height, Mean A – Mean crown projection area (m²), Σ S – Cumulative surface area

The market value of firewood for household use ranges between 750 and 850 lei/m³ (1 leu = 0,2 Euro), referring to processed logs cut into 30–50 cm lengths and delivered to distribution centers. In the case of firewood, the usable volume includes not only the trunk but also thick and secondary branches, commonly referred to as mixed firewood, which typically adds an additional 25% to the trunk volume. This percentage was adopted in consideration of the harsh environmental conditions in which downy oak grows in Dobrogea. Although the trees develop in full sunlight and without competition, factors that generally encourage crown expansion, stressful site conditions lead to reduced crown development and limited branching, as the trees allocate most of their energy to trunk growth and survival. The total wood volume per tree, including trunk and branches, is calculated as: V total = V trunk + V trunk x 0.25. For the 3-hectare plot, the volume of thick and secondary branches, and treetop sections is: 16.2 m³ for downy oak, 0.3 m³ for oriental hornbeam. On a per-hectare basis, this equates to 5.4 m³/ha for downy oak, respectively 0.1 m³/ha for oriental hornbeam. The price for this category of firewood may reach up to 300 lei/m³. Given the severe environmental conditions on the pastures of Dobrogea, the exploitation of downy oak wood for industrial purposes is not feasible, particularly considering its ecological and historical value. Nevertheless, the economic evaluation of silvopastoral systems highlights the potential of these pastures from a productive perspective as well. In such systems, only dead or heavily declining trees should be removed, in line with sustainable management practices. Downy oak (*Quercus pubescens*) produces acorns, which serve as a valuable source of nutrients, including proteins, lipids, carbohydrates, mineral salts, and vitamins (CORLĂȚEANU, 1984; NESTEROV et al., 2006). In silvopastoral system, particularly on pastures where trees benefit from increased light and space downy oak exhibits more frequent and abundant fruiting compared to individuals growing in closed forest stands. However, under such conditions, acorns tend to be smaller. The species typically begins to produce acorns at the age of 30 to 40 years. While heavy mast fruiting years occur every 4 to 6 years, downy oak generally produces at least moderate quantities of fruit annually. The intensity of fruiting is influenced by various factors, including climate (temperature and drought conditions), soil characteristics, and physiological stress (e.g., water scarcity, pruning, and disease incidence). Although no acorn yield measurements were conducted in the study area, estimates from forest-grown oaks suggest an annual production of 600 to 1,200 kg/ha during mast years (NESTEROV et al., 2006). The labor cost for collecting one kilogram of acorns ranges from 8 to 10 lei/kg, based on the national document Unified Time and Production Norms for Forestry Works (MAPPM_RNP, 1997), under conditions of average fruiting. We added to this the commercial markup of the reseller i, resulting the final price of one kilogram of downy oak acorns. From a forest-protective perspective, downy oak plays a critical role in establishing forest vegetation in arid, drought-prone areas such as the Dobrogean Plateau, where atmospheric and edaphic dryness constrain other species (ȘOFLETEA & CURTU, 2001). It can also be valued for its ecosystem services, such as microclimate improvement, providing shade for grazing animals, and contributing to landscape value. Based on weighted average calculations within the ASP system, where 41.32% of the area was under downy oak canopy and 58.68% was open pasture without tree cover, the average milk yield reached 2,400 liters/ha, representing a 30% increase compared to the adjacent open field without shade (Table 3). This improvement is likely due to ameliorated microclimatic conditions, such as reduced heat stress and increased animal welfare under partial canopy cover.

Table 3

An economic evaluation of the ASP system compared to pasture without trees

Specification	Pasture system		
	ASP	FA	Positive difference in favor of ASP, %
Cow milk production (L/ha/year)	2400	1850	23
Value (x 0,5 €/Liter)	1200	925	23
Timber m3/ha at 120 year	28.04	-	x
Timber m3/year	0.234	-	x
Value (x 160 €/m3)	37	-	x
Firewood m3/ha at 120 year	5.49	-	x
Firewood m3/year	0.04	-	x
Value (x 60 €/m3)	3	-	x
Acorn kg/ha/year	75	-	x
Value (x 1.8 €/kg)	135	-	x

Total annual value	1375	925	33
FA = without trees – open fields			

Over its 120-year growth period of the trees, 28.04 m³ of timber and 5.49 m³ of firewood represent an average yearly value of around €40. To this, the contribution of acorns, averaging 75 kg/year, is added, with an estimated market value of €135/year. Taking into consideration the total annual economic benefits of silvopastoral systems (ASP) with downy oak (*Quercus pubescens*), including milk production, acorn yield, timber and firewood, the value reaches €1,375/year. This represents a 33% increase compared to the €925/year generated solely by milk production on adjacent pastures without trees (based on a conversion rate of €1 = 5 lei). These findings underscore the superior economic performance of ASP systems in the Dobrogea region, particularly those incorporating downy oak when compared to traditional open pastures.

CONCLUSIONS

Pastures within agrosilvopastoral (ASP) systems incorporating *Quercus pubescens* in the Dobrogea region demonstrate superior productivity and economic value compared to pastures without trees. Milk production in the studied ASP system reaches 2,400 liters per hectare, representing a 23% increase compared to 1,850 L/ha on adjacent treeless pastures. The total annual economic value generated by the agrosilvopastoral (ASP) system with downy oak (*Quercus pubescens*), comprising milk (€1,200), acorns (€135), and timber and firewood (€40), amounts to €1,375 per hectare (at an exchange rate of €1 = 5 RON). This represents a 33% increase compared to the €925/ha derived solely from milk production on grassland without trees. These values highlight the importance of conserving and expanding ASP systems, particularly under the growing pressures of climate change, due to their higher economic performance and enhanced ecological resilience.

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RESEARCH ON THE BEHAVIOR OF PERENNIAL GRASSES AND LEGUMES IN SIMPLE AND COMPLEX MIXTURES IN THE CONDITIONS OF THE MOLDOVIAN FOREST-STEPPE

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Abstract

Due to the low productivity of permanent grasslands, recent research has focused on sown temporary grasslands, which offer a high potential for production and superior forage quality. This paper presents the results of a bifactorial experiment conducted in the spring of 2024 at the Ezăreni Farm (USV Iași), with the objective of evaluating the influence of the species or mixture of perennial grasses and legumes,and fertilization on plant development in the first year of vegetation. The factors studied were A – the sown species or mixture (10 graduations) and B - the level of fertilization with mineral fertilizers (4 graduations). Observations were made on the number of shoots/m² and the height of the plants at harvest. The results showed that complex mixtures including species such as Medicago sativa and Festuca pratensis generated the highest value of the number of shoots, especially under conditions of high fertilization ($N_{100}P_{100}K_{100}$). Plant height was significantly influenced by the presence of Onobrychis viciifolia, especially in the intensively fertilized variants. The conclusions highlight the efficiency of using perennial mixtures and balanced fertilization in increasing the productive potential of temporary meadows, in the context of climate change

Keywords: *temporary meadows, mineral fertilization, plant height, yield.*

INTRODUCTION

Due to the low productivity of permanent grasslands, the need was felt to closely study temporary sown grasslands. Temporary grasslands are sown and managed with the expectation of achieving high production and high-quality forage (Søegaard K. et al. 2007). Research conducted at national and international levels has shown the benefits of growing forage plants but has also led to the establishment of standard mixtures of such forage plants.

Interspecific competitiveness was influenced by the percentage of participation in the sowing rate of the species in the mixture, the mineral fertilizers used, the biological characteristics of the studied species and the climatic conditions specific to each crop year (Vîntu V. et al. 2024). Fertilization with complex mineral fertilizers leads in most cases to higher dry matter production regardless of the species or mixture of perennial grasses and legumes (Zaiț T. et al. 2022).

The composition of the mixture has a significant effect on biomass yield and quality indices, rather than on species diversity (Tahir M. et al., 2022). Research results have shown that the association of white clover with medium-sized perennial grass could provide the best option for temporary meadows (Piano E. et al., 1995). Some grass species are also studied for their anti-erosion effect, such as *Festuca arundinacea plants,* but also their cultivation on temporary meadows mixed with other grasses or perennial legumes, grass strips in vineyards and orchards, the biomass production being successfully used as green mass or hay in feeding farm animals. (Țîței V. et al., 2019; 2022).

The quality of the forage obtained from temporary pastures is influenced by the doses of fertilizers applied, the proportion of the species' participation in the sowing rate, but also by the climatic conditions during the exploitation period. (Boureanu C. et al., 2016). The quality of forage obtained from sown meadows is influenced by the percentage of participation of each species in the mixture, but also the different degree of fertilization (Samuil C. et al., 2012). Since the 20th century, research on complex mixtures of perennial grasses and legumes has shown benefits in their cultivation, as well as a standardization of perennial grass and legume species across different cropping areas (Sanderson M.A. et al., 2005).

The productivity of grasslands in dry areas can be influenced by the choice of more drought-tolerant plants for sowing. (Skinner R.H. et al., 2004). Moderate use of mineral and organic fertilizers brings higher yields, also having a positive effect on biodiversity and forage quality (Samuil C. et al., 2018).

MATERIAL AND METHOD

The experiment was established in the experimental field of the Ezăreni Farm (47°05'-47°10' north latitude and 27°28'-27°33' east longitude) belonging to the Didactic Station of the Iasi University of Life Sciences, according to the method of subdivided plots with two factors (of the 10x4 type), in 3 repetitions, having the dimensions of a plot of 1 x 9 m (9 m2), the total surface of the experience being of 1280 m^2.

The goal is to develop and standardize mixtures of perennial forage species under the conditions of climate change in the experimental area. In the first part, the influence of the mixture and fertilization on the growth and development of plants within the mixtures will be studied.

The study factors were:

Factor A: the species or mixture of perennial grasses and legumes, with 10 gradations: a_1– *Onobrychis viciifolia* Scop. (100%) (control); a_2 – *Onobrychis viciifolia* Scop. (75%) and *Bromus inermis* Leyss. (25%); a_3-*Onobrychis viciifolia* Scop. (50%) and *Bromus inermis* Leyss. (50%); a_4-*Onobrychis viciifolia* Scop. (25%) and *Bromus inermis* Leyss. (75%); a_5 – *Medicago sativa* L. (100%); a_6 – *Medicago sativa* L. (75%) and *Festuca pratensis* (25%); a_7 - *Medicago sativa* L. (50%) and *Festuca pratensis* (50%); a_8 – *Medicago sativa* L. (25%) and *Festuca pratensis* (75%); a_9 – *Medicago sativa* L. (20%), *Lotus corniculatus* L. (15%); *Festuca pratensis* (30%); *Lolium perenne* L. (10%) and *Dactylis glomerata* L. (25%) and a_{10} – *Onobrychis viciifolia* Purpose. (20%), *Lotus corniculatus* L. (15%); *Agropyron pectiniforme* L. (30%); *Bromus inermis* Leyss. (25%) and *Lolium perenne* L. (10%).

Factor B - fertilization with mineral fertilizers, with 4 graduations: b_1–unfertilized (C); b_2-$N_{50}P_{50}K_{50}$; b_3-$N_{75}P_{75}K_{75}$; b_4-$N_{100}P_{100}K_{100}$.

Observations and determinations carried out in the field during the entire vegetation period, the following indices being observed: number of shoots/m; plant height at harvest (cm).

The amount of green mass per hectare was determined by weighing the production obtained after each scythe on the harvestable surface of 8 m^2 and reported per hectare. The content in dry matter (s.u.) was determined by drying in an oven, at a temperature of 105ºC, for 3 hours; standard - SR ISO 6496/2001. Height, number of shoots and and yield data were processed using ANOVA, applying the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

The study analyzed the influence of fertilization with complex mineral fertilizers based on nitrogen, phosphorus and potassium on the number of shoots formed by the time of harvest, in the species *Onobrychis viciifolia* and *Medicago sativa*, cultivated both alone and in simple and complex mixtures (table 1).

The data obtained revealed a significant variation in the number of shoots depending on the combination of species type (or mixture) and fertilization level applied.

Thus, the values ranged between 508 shoots/m², in variant a_1 b_1 (*Onobrychis viciifolia* 100%, unfertilized), and 3092 shoots/m², in variant $a_{10}b_4$ (complex mixture consisting of *Medicago sativa* 20%, *Lotus corniculatus* 15%, *Festuca pratensis* 30%, *Lolium perenne* 10% and *Dactylis glomerata* 25%), fertilized with the maximum dose of $N_{100}P_{100}K_{100}$ (table 1).

Table 1

Influence of the interaction between the species or mixture of perennial grasses and legumes and fertilization with mineral fertilizers on the number of shoots/m^2, in the first year of vegetation

Variant		Number of shoots	Difference		Meaning
		Shoots/m^2	Shoots/m^2	%	
		Control: a_1b_1 - *O.v.* (100%), unfertilized			
a_1 - *O.v.* (100%) (mt.)	b_1 - unfertilized (mt.)	508	Control	100	Control
	b_2 - $N_{50}P_{50}K_{50}$	620	112	122,0	
	b_3 - $N_{75}P_{75}K_{75}$	664	156	130,7	
	b_4 - $N_{100}P_{100}K_{100}$	736	228	144,9	
a_2 - *O.v.* (75%) + *B.i.* (25%)	b_1 - unfertilized	792	284	155,9	
	b_2 - $N_{50}P_{50}K_{50}$	956	448	188,2	**
	b_3 - $N_{75}P_{75}K_{75}$	1072	564	211,0	***
	b_4 - $N_{100}P_{100}K_{100}$	1124	616	221,3	***
a_3 - *O.v.* (50%) + *B.i.* (50%)	b_1 - unfertilized	1000	492	196,9	**
	b_2 - $N_{50}P_{50}K_{50}$	1160	652	228,3	***
	b_3 - $N_{75}P_{75}K_{75}$	1240	732	244,1	***
	b_4 - $N_{100}P_{100}K_{100}$	1348	840	265,4	***
a_4 - *O.v.* (25%) + *B.i.* (75%)	b_1 - unfertilized	688	180	135,4	
	b_2 - $N_{50}P_{50}K_{50}$	744	236	146,5	
	b_3 - $N_{75}P_{75}K_{75}$	880	372	173,2	*
	b_4 - $N_{100}P_{100}K_{100}$	964	456	189,8	**
a_5 - *M.s.* (100%)	b_1 - unfertilized	1200	692	236,2	***
	b_2 - $N_{50}P_{50}K_{50}$	1700	1192	334,6	***
	b_3 - $N_{75}P_{75}K_{75}$	1308	800	257,5	***
	b_4 - $N_{100}P_{100}K_{100}$	1816	1308	357,5	***
a_6 - *M.s.* (75%) + *F.p.* (25%)	b_1 - unfertilized	1492	984	293,7	***
	b_2 - $N_{50}P_{50}K_{50}$	2100	1592	413,4	***
	b_3 - $N_{75}P_{75}K_{75}$	2508	2000	493,7	***
	b_4 - $N_{100}P_{100}K_{100}$	2668	2160	525,2	***
a_7 - *M.s.* (50%) + *F.p.* (50%)	b_1 - unfertilized	1764	1256	347,2	***
	b_2 - $N_{50}P_{50}K_{50}$	2024	1516	398,4	***
	b_3 - $N_{75}P_{75}K_{75}$	2100	1592	413,4	***
	b_4 - $N_{100}P_{100}K_{100}$	2664	2156	524,4	***
a_8 - *M.s.* (25%) + *F.p.* (75%)	b_1 - unfertilized	2160	1652	425,2	***
	b_2 - $N_{50}P_{50}K_{50}$	2284	1776	449,6	***
	b_3 - $N_{75}P_{75}K_{75}$	2600	2092	511,8	***
	b_4 - $N_{100}P_{100}K_{100}$	2704	2196	532,3	***
a_9 - *M.s.* (20%) + *L.c.* (15%) + *F.p.* (30%) + *L.p.* (10%) + *D.g.* (25%)	b_1 - unfertilized	2236	1728	440,2	***
	b_2 - $N_{50}P_{50}K_{50}$	2732	2224	537,8	***
	b_3 - $N_{75}P_{75}K_{75}$	2968	2460	584,3	***
	b_4 - $N_{100}P_{100}K_{100}$	3092	2584	608,7	***
a_{10} - *O.v.* (20%) + *L.c.* (15%) + *A.p.* (30%) + *B.i.* (25%) + *L.p.* (10%)	b_1 - unfertilized	1440	932	283,5	***
	b_2 - $N_{50}P_{50}K_{50}$	1800	1292	354,3	***
	b_3 - $N_{75}P_{75}K_{75}$	1592	1084	313,4	***
	b_4 - $N_{100}P_{100}K_{100}$	1936	1428	381,1	***
		DL 5% =	319		
		DL 1% =	423		
		DL 0,1% =	547		

The highest values of shoot number were recorded in the variants that included *Medicago sativa* and *Festuca pratensis* , grown in various mixtures, both simple and complex.

In general, regardless of the composition of the species used, fertilization with complex mineral fertilizers resulted in a significant increase in the number of shoots per unit area.

Compared to the control variant, all other variants analyzed presented very statistically significant differences.

During the observations, the height of the shoots at the time of harvest was determined for the species *Onobrychis viciifolia* and *Medicago sativa* , cultivated either individually or in simple or complex mixtures, under different fertilization conditions with complex mineral fertilizers based on nitrogen, phosphorus and potassium (table 2).

The analysis of the interaction between the type of species (or mixture) and the applied fertilization revealed values ranging from 36.7 cm, in variant a_8 b_1 (simple mixture consisting of *Medicago sativa* 25% + *Festuca pratensis* 75%, unfertilized), and 77.5 cm, in variant a_1 (*Onobrychis viciifolia* 100%), fertilized with the maximum dose of $N_{100}P_{100}K_{100}$ (table 2).

Regarding plant height, the highest values were recorded in the variants where Onobrychis viciifolia Scop. was present, either grown alone or in mixtures.

In general, fertilization with nitrogen and phosphorus-based mineral fertilizers led to an increase in plant height, regardless of the type of species or mixture used. With the exception of the variant grown exclusively with *Onobrychis viciifolia*, all other fertilized variants showed statistically significant differences compared to the control (table 2).

Regardless of the fertilization variant or the composition of the mixture, climatic conditions, especially the amount of precipitation, significantly influenced the processes of germination, emergence, growth and development.

The height of the plants in the first cut, in the first year of vegetation, was largely determined by the level of precipitation recorded in the first part of the vegetation period. In the first year of vegetation, a single mowing was carried out. The analysis of the data obtained shows that the dry matter (DM) yields varied significantly depending on the species composition and the fertilization regime applied (table 3). The lowest yields were recorded in variant a_8, a simple mixture consisting of *Medicago sativa* (25%) and *Festuca pratensis* (75%), unfertilized, with a production of 1776 kg/ha DM. At the opposite pole, variant a_1, represented by *Onobrychis viciifolia* (100%) grown in monoculture and fertilized with $N_{100}P_{100}K_{100}$, recorded the highest production, of 5745 kg/ha DM (table 3).

Table 2

Influence of the interaction between the species or mixture of perennial grasses and legumes and fertilization with mineral fertilizers on plant height, in the first year of vegetation

Variant		Plant height	Diferența		Meaning
		cm	cm	%	
		Control: a_1b_1 - *O.v.* (100%), unfertilized			
a_1 - *O.v.* (100%) (mt.)	b_1 - unfertilized (mt.)	77,5	Control	100	Control
	b_2 - $N_{50}P_{50}K_{50}$	75,3	-2,2	97,2	
	b_3 - $N_{75}P_{75}K_{75}$	75,3	-2,2	97,2	
	b_4 - $N_{100}P_{100}K_{100}$	72,0	-5,5	92,9	
a_2 - *O.v.* (75%) + *B.i.* (25%)	b_1 - unfertilized	71,2	-6,3	91,8	
	b_2 - $N_{50}P_{50}K_{50}$	74,8	-2,7	96,6	
	b_3 - $N_{75}P_{75}K_{75}$	69,3	-8,2	89,5	
	b_4 - $N_{100}P_{100}K_{100}$	71,2	-6,3	91,8	
a_3 - *O.v.* (50%) + *B.i.* (50%)	b_1 - unfertilized	69,8	-7,7	90,1	
	b_2 - $N_{50}P_{50}K_{50}$	70,0	-7,5	90,3	
	b_3 - $N_{75}P_{75}K_{75}$	69,2	-8,3	89,2	
	b_4 - $N_{100}P_{100}K_{100}$	68,8	-8,7	88,8	
a_4 - *O.v.* (25%) + *B.i.* (75%)	b_1 - unfertilized	72,7	-4,8	93,8	
	b_2 - $N_{50}P_{50}K_{50}$	69,7	-7,8	89,9	
	b_3 - $N_{75}P_{75}K_{75}$	75,3	-2,2	97,2	
	b_4 - $N_{100}P_{100}K_{100}$	73,3	-4,2	94,6	
a_5 - *M.s.* (100%)	b_1 - unfertilized	45,0	-32,5	58,1	ooo
	b_2 - $N_{50}P_{50}K_{50}$	46,2	-31,3	59,6	ooo
	b_3 - $N_{75}P_{75}K_{75}$	42,8	-34,7	55,3	ooo
	b_4 - $N_{100}P_{100}K_{100}$	50,3	-27,2	64,9	oo
a_6 - *M.s.* (75%) + *F.p.* (25%)	b_1 - unfertilized	44,2	-33,3	57,0	ooo
	b_2 - $N_{50}P_{50}K_{50}$	45,7	-31,8	58,9	ooo
	b_3 - $N_{75}P_{75}K_{75}$	44,7	-32,8	57,6	ooo
	b_4 - $N_{100}P_{100}K_{100}$	47,3	-30,2	61,1	oo
a_7 - *M.s.* (50%) + *F.p.* (50%)	b_1 - unfertilized	49,3	-28,2	63,7	oo
	b_2 - $N_{50}P_{50}K_{50}$	47,0	-30,5	60,6	oo
	b_3 - $N_{75}P_{75}K_{75}$	49,2	-28,3	63,4	oo
	b_4 - $N_{100}P_{100}K_{100}$	53,8	-23,7	69,5	o
a_8 - *M.s.* (25%) + *F.p.* (75%)	b_1 - unfertilized	36,7	-40,8	47,3	ooo
	b_2 - $N_{50}P_{50}K_{50}$	45,8	-31,7	59,1	ooo
	b_3 - $N_{75}P_{75}K_{75}$	44,5	-33,0	57,4	ooo
	b_4 - $N_{100}P_{100}K_{100}$	41,5	-36,0	53,5	ooo
a_9 - *M.s.* (20%) + *L.c.* (15%) + *F.p.* (30%) + *L.p.* (10%) + *D.g.* (25%)	b_1 - unfertilized	43,2	-34,3	55,7	ooo
	b_2 - $N_{50}P_{50}K_{50}$	44,8	-32,7	57,8	ooo
	b_3 - $N_{75}P_{75}K_{75}$	45,3	-32,2	58,5	ooo
	b_4 - $N_{100}P_{100}K_{100}$	47,7	-29,8	61,5	oo
a_{10} - *O.v.* (20%) + *L.c.* (15%) + *A.p.* (30%) + *B.i.* (25%) + *L.p.* (10%)	b_1 - unfertilized	59,0	-18,5	76,1	o
	b_2 - $N_{50}P_{50}K_{50}$	56,5	-21,0	72,9	o
	b_3 - $N_{75}P_{75}K_{75}$	59,2	-18,3	76,3	o
	b_4 - $N_{100}P_{100}K_{100}$	66,3	-11,2	85,6	
		DL 5% =	17,9		
		DL 1% =	23,7		
		DL 0,1% =	30,6		

Table 3

Influence of the interaction between the species or mixture of perennial grasses and legumes and fertilization with mineral fertilizers on the production of DM in the first year of vegetation

Variant		Production of DM	Difference		Meaning
		kg/ha	kg/ha	%	
a_1 - *O.v.* (100%) (mt.)	b_1 - unfertilized (mt.)	3263	Control	100	Control
	b_2 - $N_{50}P_{50}K_{50}$	5159	1895,5	158,1	***
	b_3 - $N_{75}P_{75}K_{75}$	4444	1181,0	136,2	***
	b_4 - $N_{100}P_{100}K_{100}$	5745	2482,0	176,1	***
a_2 - *O.v.* (75%) + *B.i.* (25%)	b_1 - unfertilized	3854	590,5	118,1	**
	b_2 - $N_{50}P_{50}K_{50}$	3913	650,0	119,9	***
	b_3 - $N_{75}P_{75}K_{75}$	3963	699,2	121,4	***
	b_4 - $N_{100}P_{100}K_{100}$	5267	2003,3	161,4	***
a_3 - *O.v.* (50%) + *B.i.* (50%)	b_1 - unfertilized	2893	-370,0	88,7	o
	b_2 - $N_{50}P_{50}K_{50}$	3267	3,3	100,1	
	b_3 - $N_{75}P_{75}K_{75}$	3577	314,0	109,6	
	b_4 - $N_{100}P_{100}K_{100}$	4037	773,5	123,7	***
a_4 - *O.v.* (25%) + *B.i.* (75%)	b_1 - unfertilized	2703	-560,2	82,8	oo
	b_2 - $N_{50}P_{50}K_{50}$	3884	620,7	119,0	***
	b_3 - $N_{75}P_{75}K_{75}$	5093	1830,0	156,1	***
	b_4 - $N_{100}P_{100}K_{100}$	4703	1440,0	144,1	***
a_5 - *M.s.* (100%)	b_1 - unfertilized	2703	-560,2	82,8	oo
	b_2 - $N_{50}P_{50}K_{50}$	3824	560,3	117,2	**
	b_3 - $N_{75}P_{75}K_{75}$	4994	1730,7	153,0	***
	b_4 - $N_{100}P_{100}K_{100}$	4397	1133,5	134,7	***
a_6 - *M.s.* (75%) + *F.p.* (25%)	b_1 - unfertilized	1978	-1285,0	60,6	ooo
	b_2 - $N_{50}P_{50}K_{50}$	2348	-915,0	72,0	ooo
	b_3 - $N_{75}P_{75}K_{75}$	2620	-643,7	80,3	ooo
	b_4 - $N_{100}P_{100}K_{100}$	2838	-425,2	87,0	o
a_7 - *M.s.* (50%) + *F.p.* (50%)	b_1 - unfertilized	2673	-590,0	81,9	oo
	b_2 - $N_{50}P_{50}K_{50}$	2743	-520,8	84,0	oo
	b_3 - $N_{75}P_{75}K_{75}$	2971	-292,5	91,0	
	b_4 - $N_{100}P_{100}K_{100}$	3163	-100,0	96,9	
a_8 - *M.s.* (25%) + *F.p.* (75%)	b_1 - unfertilized	1776	-1487,5	54,4	ooo
	b_2 - $N_{50}P_{50}K_{50}$	2914	-349,7	89,3	o
	b_3 - $N_{75}P_{75}K_{75}$	2167	-1096,0	66,4	ooo
	b_4 - $N_{100}P_{100}K_{100}$	3712	449,0	113,8	*
a_9 - *M.s.* (20%) + *L.c.* (15%) + *F.p.* (30%) + *L.p.* (10%) + *D.g.* (25%)	b_1 - unfertilized	3485	222,0	106,8	
	b_2 - $N_{50}P_{50}K_{50}$	3633	370,0	111,3	*
	b_3 - $N_{75}P_{75}K_{75}$	4867	1603,3	149,1	***
	b_4 - $N_{100}P_{100}K_{100}$	4306	1043,0	132,0	***
a_{10} - *O.v.* (20%) + *L.c.* (15%) + *A.p.* (30%) + *B.i.* (25%) + *L.p.* (10%)	b_1 - unfertilized	2893	-370,0	88,7	o
	b_2 - $N_{50}P_{50}K_{50}$	3233	-30,0	99,1	
	b_3 - $N_{75}P_{75}K_{75}$	3698	435,0	113,3	*
	b_4 - $N_{100}P_{100}K_{100}$	4801	1537,3	147,1	***
		DL 5% =	345,4		
		DL 1% =	458,2		
		DL 0,1% =	591,9		

Research has shown that the application of mineral fertilizers based on nitrogen, phosphorus and potassium had a positive effect on production, with most of the differences between the variants being statistically significant.

Production was influenced both by the fertilization dose and by the species or combinations used. At the first mowing, in the first year of vegetation, the highest productions were obtained in variant a_1, where *Onobrychis viciifolia* was grown alone and fertilized with high doses of NPK. At the same time, the variants in which this species was predominant generated higher productions even under moderate fertilization conditions or even in the absence of fertilization.

Good yields were also obtained in the case of complex mixtures, such as variants a_8 and a_9, where statistically significant production increases were recorded (table 3).

CONCLUSIONS

In the first year of vegetation, the highest number of shoots was recorded in the variants that included the species *Medicago sativa* L. and *Festuca pratensis* L., cultivated in both simple and complex mixtures.

The average number of shoots per square meter varied between 632 shoots/m² in variant a_1, composed exclusively of *Onobrychis viciifolia* Scop. (100%), and 2757 shoots/m² in variant a_9, a complex mixture composed of *M.s.* (20%), *L.c.* (15%), *F.p.* (30%), *L.p.* (10%) and *D.g.* (25%). The height of the shoots, in the first year of vegetation, ranged between 36.7 cm in variant a_8b_1 (simple mixture: *M.s.* 25% + *F.p.* 75%) and 77.5 cm in variant a_1 (*O.v.* 100%), fertilized with $N_{100}P_{100}K_{100}$.The highest plant height values were observed in the variants in which the species *Onobrychis viciifolia* Scop. was present.

The vegetative development of plants is significantly influenced both by the supply of essential nutrients: nitrogen, phosphorus and potassium, provided by fertilization, and by the genetic potential of the cultivated species.

In the first year of vegetation, a single mowing was carried out, and dry matter production showed significant variations, ranging from 1776 kg/ha DM in variant a_8 - simple mixture consisting of *Medicago sativa* (25%) and *Festuca pratensis* (75%), unfertilized - and 5745 kg/ha DM in variant a_1, where *Onobrychis viciifolia* (100%) fertilized with $N_{100}P_{100}K_{100}$.

The highest productions were obtained in the variants in which *Onobrychis viciifolia* Scop. was present in a proportion greater than 50%, highlighting the favorable influence of this species on the level of production.

The application of mineral fertilizers based on nitrogen, phosphorus and potassium determined significant increases in dry matter production in the first year of vegetation, the differences between the variants being, in most cases, statistically significant.

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EVALUATION OF MEADOW FESCUE (*FESTUCA PRATENSIS* HUDS.) GERMPLASM FOR BREEDING PURPOSES

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Abstract

The aim of research is the evaluation of the germplasm through observations and measurements to choose valuable resources of initial breeding material. Were analyzed 16 accessions of Festuca pratensis Huds., in order to evaluate the genetic diversity within and among the breeding material sources concerning: heading date, abundance of vegetative and generative tillers, plant height, leaf diseases resistance, shape of plant and the correlation between traits. The traits investigated were analysed through the correlation matrix to estimate the correlations between the morpho - physiological characters The vegetative tillers are distinct significant positive correlation (0,81) with generative tillers and with plant height (0,77) and negative correlation with rust resistance (-0,06) and with heading date (- 0,22).The generative tillers are distinct significant positive correlation (0,80) with plant height also.

Keywords: *genotypes, meadow fescue, disease resistance, generative tillers, vegetative tillers,*

INTRODUCTION

The meadow fescue is one of the most important perennial forage grasses for meadows and grasslands. It is a medium-sized species, with rich foliage and fine leaves, which gives it a very high production and high nutritional value. It is resistant to frost and that is why it is very widespread in countries with harsh winters, particularly in the northern hemisphere. (VARGA et al, 1998). The cultivation zone is from the steppe area, up to the spruce forests. It grows best on clayey, heavy, nutrient-rich soils, but it can be found on many types of soil, except for dry or poor ones. (MOCANU et al.,2021). The forage mixtures which include meadow fescue are used both by grazing and mowing, for hay and semi-hay, contributing to ensuring quality forage. (MOGA I., SCHITEA M., 2000). Meadow fescue is compatible with the most important forage legumes (white and red clover, alfalfa, sainfoin) and perennial forage grasses, including timothy (*Phleum pratense*), tall fescue (*Festuca arundinacea*) and pernnial ryegrass (*Lolium perenne*). *Festuca pratensis* has a great ability to hybridize with perennial ryegrass (*Lolium perenne*) and Italian ryegrass (*Lolium multiflorum*). The prime aim in *Festulolium* cultivar development has been to combine the agronomically desirable traits of *Lolium* (high forage yield and fast installation) and the stress resistance (frost and diseases resistance) of *Festuca* species. Suitable amphiploid and introgression breeding approaches have been developed (HUMPREYS M.W., Zwierzkowsky, Z., 2020). The genetic variability of all traits important for breeding proces represents a basic prerequisite for selection, which ensures the succes of the breeding process. (BABIC et al, 2018, 2023). BABIC et al. (2018) found the presence of significant variability within meadow fescue wild populations and cultivars for studied morphological, productive and quality traits. THOMAS et al (1996) found a considerable genetic diversity within *Festuca pratensis* for yield potential and for survival and high yield stability during both extreme drought and osmotic stress.

The main objectives of the breeding activity is to create cultivars with both high forage and seed yield, good forage quality, drought tolerance, good diseases resistance and persistency. In the present study a phenotypic characterization is given for 16 accessions of *Festuca pratensis* in order to evaluate the genetic diversity within and among the breeding material sources concerning: heading date, abundance of vegetative and generative tillers, plant height, leaf diseases resistance, shape of plant and the correlation between traits. Forage analysis using NIR measurement has been a major application of the technique largely due to the work of J.S. Shenk, M. Westerhaus, W. Barton, G. Marten, N. Martin, and a host of others who improved upon the technique and worked toward it's widespread use and acceptance among scientists as a valid analytical technique.

MATERIAL AND METHOD

The experiment was conducted in a field trial of the Research and Development Institute for Grasslands - Brașov, during the years 2023-2024. The plant material used in this experiment was represented by 16 accessions - breeding lines, with a total of 623 individual plants. The plants were obtained by sowing in March 2023, in the greenhouse, in rows in trays, followed by individual transplanting into small plastic pots. Maintenance works were applied: watering, weeding, phytosanitary treatments to prevent *Pythium* infections, repeated pruning to stimulate twinning. Particular attention is paid to ensuring equal treatment to each plant to avoid variability due to external factors, so that even from this early phase individual plants express their true genetic potential. When the seedlings were sufficiently well developed, with vigorous shoots and a well-developed root system, they were transplanted into the field, as individual plants, at equal distances of 50 cm, 10 plants per row and 36 rows/per block. The meteorological conditions in the years 2023-2024 (table 1) indicate a drier and warmer period compared to the multiannual average. Considering the recorded temperatures, in both years the values exceeded the multiannual average, with 0,6°C in 2023 and with 2.7°C in 2024. From the point of view of precipitation, the year 2023 recorded a total deficit of -182.8 mm and of -121,3 mm during the vegetation period, and in 2024 a total deficit of -22.6 mm and of 43,2 mm in the vegetation period compared to the multiannual average.

Table 1

Meteorological conditions from Brașov stationary 2023-2024

Years	**Annual average I - XII**	**Deviation**	**Vegetation period IV - IX**	**Deviation**
Temperature (°C)				
2023	10,1	+2,3	14,8	+0,6
2024	11,4	+3,6	17,6	+2,7
Average 59 years	7.8	0	14.2	0
Precipitation (mm)				
2023	570,4	-182,8	407,8	-121,3
2024	730,6	-22,6	485.9	- 43,2
Average 59 years	753.2	0	529.1	0

During the vegetation period of 2024 year, the following observations and determinations have been made heading date (inflorescence emergence), growth habit (before inflorescences emergence) (E – erect, S - semi-erect, P - prostate), number of vegetative tillers, scale 1 – 5, number of generative tillers, scale 1-5, plant heigh, the distance in cm from the plant base to the of panicle after anthesis, resistance to rust (% of healthy plants). The morphological and phenological characters were scored by visual inspection or measurements. The recorded data were statistically processed in the Statistica 7 software package.

RESULTS AND DISCUSSIONS

Regarding precocity, there were 8 days between the earliest: 6 May and the latest: 14 May, most of the genotypes having the heading date during 7-10 May. The growth habit was in most cases erect: 8 genotypes, followed by semi-erect: 5 genotypes and semi-erect - prostrate: 2 genotypes and prostrate: 1 genotype. The shape of the bush allows selection for different ways of use. Regarding the number of vegetative and generative tillers, genotypes with both vegetative tillers and abundant generative tillers were highlighted: Trans 2/2019, Trans 2/ 2020, Trans 2 /2021, Trans 2 /2022 and the

Moldova Botanical Garden, representing valuable biological materials for a new cycle of selection. Selection for improving seed yielding capacity correlated with a high forage yield is a major objective in breeding of grass species (BALAN M., 1999). The height of the plants did not vary widely, being on average between 68.3 cm for the Trans 2/2017 and 90.8 for Trans 2/2021. Disease resistance was noted in the case of rust attack, the resistant plants being the least numerous in the Rozon accession: 31%, the most resistant being Cosmopolitan: 87.5%. Rust, transmitted by *Puccinia* sp is the most damaging grass disease both in frequency and intensity of attack. (Table 2)

Table 2

Traits evaluation of *Festuca pratensis* accessions

Nr crt.	Accessions	Plants nr	Heading date	Growth habit	Vegetative tillers	Generative tillers	Plant height (cm)	Rust resistance (%)
1	Trans 2/2015	38	7.05	SE	4	4	77.5	73.7
2	Trans 2/2017	47	10.05	P	3	3	68.3	55.3
3	Trans 2/2018	39	6.05	SE	4	4	78.0	61.5
4	Trans 2/2019	49	9.05	E	5	5	79.8	67.3
5	Trans 2/2020	40	9.05	E	5	5	80.3	67.5
6	Trans 2/2021	49	9.05	E	5	5	90.8	65.3
7	Trans 2/2022	40	9.05	E	5	5	85.8	60.0
8	Trans 2/iz 2021	40	7.05	E	5	5	83.0	56.7
9	Barv 2020	40	10.05	SE	5	4	78.3	42.1
10	Barv 2021	40	8.05	E	4	5	75.5	40.0
11	Rozon	40	10.05	E	4	5	84.5	31.0
12	Grad Bot MD	50	7.05	E	5	5	86.5	57.6
13	Cosmopolitan	50	10.05	SE	4	4	78.3	87.5
14	Tampa 2016	40	10.05	SE-P	3	3	71.8	72.5
15	Tampa 2017	50	7.05	SE-P	4	4	76.0	53.0
16	Tampa 2018	20	14.05	SE	4	4	71.5	60.0

Disease resistance is an important factor in breeding objectives to ensure higher quality fodder production and an increased crop longevity. The results of observations and measurements were processed statistically, showing a small variation for height and heading date (cv smaller than 10%) a medium variance for vegetative and generative tillers (cv between 10 – 20%) and a high variance for resistance to rust (higher than 20%) (table 3).

Table 3

Descriptive statistic - The coefficient of variation for the studied parameters

Parameters	**Valid** N	**Mean**	**Confiden** -95.00%	**Confiden** 95.00%	**Mediu**	**Min**	**Max**	**Variance**	**Std. Dev.**	**Std. Error**	**CV %**
Vegetative tillers	16	4.3125	3.93728	4.68772	4	3	5	0.4958	0.7042	0.70415	16.3
Generative tillers	16	4.375	3.99198	4.75802	4.5	3	5	0.5167	0.7188	0.7188	16.4
Height (cm)	16	79.1188	75.92707	82.31043	78.3	68.3	90.8	35.876	5.9897	5.98968	7.6
Rust resist (%)	16	59.4375	52.04861	66.82639	66	31	87.5	192.28	13.866	13.8664	23.3
Heading date	16	69.75	68.89079	70.60921	70	67	73	2.6	1.6125	1.61245	2.3

The traits investigated were analysed through the correlation matrix to estimate the correlations between the morpho - physiological characters The vegetative tillers are distinct significant positive correlation (0,81) with generative tillers and with plant height (0,77) and negative correlation with rust resistance (-0,06) and with heading date (- 0,22). The generative tillers are distinct significant positive correlation (0,80) with plant height also (table 4).

Table 4

The correlation matrx

Parameters	Vegetative tillers	Generative tilleres	Height (cm)	Rust reistance (%)	Heading date
Vegetative tillers	1,00	0.81***	0.77***	-0.06	-0.22
Generative tillers		1,00	0.80***	-0.26	-0.26
Height (cm)			1,00	-0.07	-0.3
Rust resist (%)				1,00	-0.001
Heading date					1,00

Following the calculations made through the principal components analyses (PCA), three components was resulted, so the first 3 components bring a variance of 92.36 %. It is found that, accepting the expression of the initial causal space, respectively of the variables under study, through a single main component, only 54.58% of the initial variance is explained. Extending the number of main components to tree, the explanation of 92.36% of the total variance is ensured (Table 5).

Table 5

Eigenvalues of correlation matrix, and related statistics

Component	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	2.7292	54.5832	2.7292	54.5832
2	1.0263	20.5269	3.7555	75.1101
3	0.8628	17.2569	4.6184	92.3670
4	0.2248	4.4957	4.8431	96.8628
5	0.1569	3.1372	5.0000	100.0000

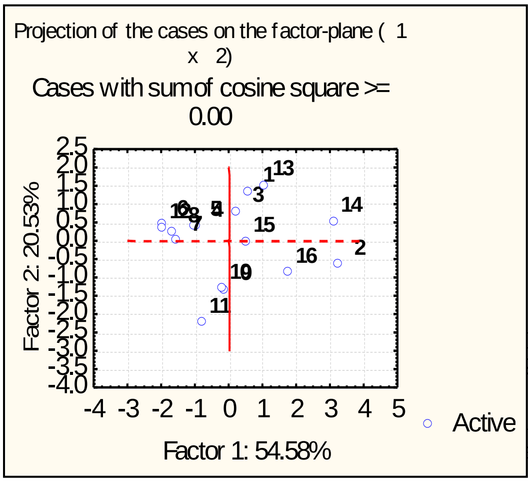
Principal component 1 (PC1) which represented 54.58 % of the total variation, includes the variables with the highest negative correlation coefficients: vegetative tilers (r=-0.90), generative tilers (r= -0.93), and plant height (r= -0,.91). Principal component 2 (PC2) which represented 20.52 % of the total variation includes the variable with positive correlation coefficients: rust resistance (r=0.20). Principal component 3 (PC3) which represented 17.25 % of the total variation include positive correlation coefficients: heading date (r=0.41) (tables 6).

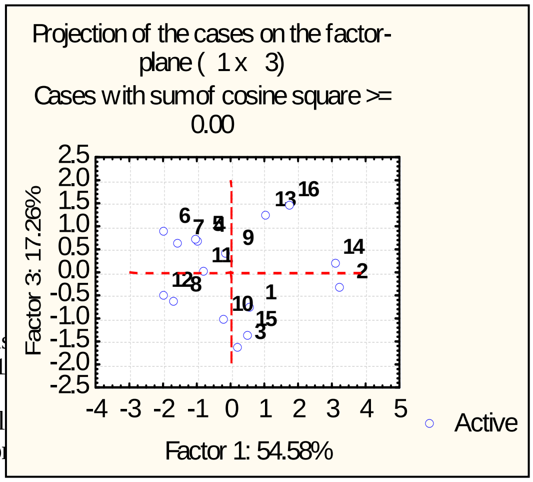
Table 6.

Factor-variable correlations, based on correlations

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Vegetative tillers	-0.9018	0.0694	0.2347	-0.3021	0.1890
Generative tillers	-0.9335	-0.1321	0.0890	-0.0444	-0.3183
Height (cm)	-0.9118	0.0953	0.1242	0.3607	0.1188
Rust resist (%)	**0.2085**	**0.9141**	0.3394	-0.0043	-0.0755
Heading date	**0.4121**	**-0.3993**	**0.8181**	0.0385	-0.0063

The genotypes Tâmpa 2016 and Trans 2/2017 represented in figure 1 a) with points 14 and 2, have a big contribution to the PC 1, namely vegetative tilers, generative tilers, and plant height. The abundance of vegetative tilers combining with the generative tillers give a high biological potential for break the existing negative correlations between seed and forage production. The Cosmopolitan (no.13) variety has positive contribution to PC 2 represented here by the rust resistance, and Rozon (no.11) have a negative contribution. In the breeding process the most resistant genotypes, with the frequency of over 80% resistant plants will be chosen. In the PC 3 (figure 1 b)), represented by heading date, the variety Tampa 2018 (no 16) has a big contribution. For identify the most valuable genotypes that could be the basis for the creation of new qualitatively and quantitatively superior synthetic combinations and the highlighting and selection of the parental forms of *Festuca pratensis* Huds., it's good respond to the principals breeding objectives: increasing the forage and seed production, disease resistance and adaptability.





CONCLUSIONS

The positive correlation between vegetative tillers, considered the most important trait for forage production and the generative tillers, the basic criteria for the phenotypic selection in the purpose of obtaining varieties with high seed production, allow us to select genotypes with both features to be combined in the new genotypes. The high coefficient of variability concerning rust resistance offers the possibility to select resistant plants to this aggressive pathogen. The observations concerning the plant habit permit us to choose similar phenotypically genotypes to ensure the uniformity of a new genotype. The observations and determinations made on individual plants allow a convergent selection of valuable genotypes regarding the breeding objectives for the creation of new and superior varieties.

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THE SYNERGY BETWEEN PLANTS AND MICROORGANISM IN HEAVY METALS REMOVAL – A SHORT REVIEW

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Abstract

Soil degradation in the presence of heavy metals represents an environmental problem with negative effects on world biomes. A multitude of methods were developed to reduce these types of pollutants, and the most effective one is bioremediation, which implies the use of plants and microorganisms. Phytoextraction is considered a promising bioremediation technique, cost-effective and sustainable for environmental recovery. The effect of this approach can be increased by the inoculation of plant roots with beneficial microorganisms. This technique is based on the relationship between plants and soil microorganisms and increases the adaptation potential of plant species to metal-rich environments. For this purpose, various microbial groups have been shown to stimulate the production of growth-supporting hormones, activate stress response mechanisms and improve nutrient availability through fixation and solubilization processes.

Keywords: grassland, microbial communities, heavy metals, pollution, bioremediation

INTRODUCTION

Soil degradation is a global environmental problem with negative effects on food security. For this reason, improving soil health is an essential challenge for sustainable agriculture (GRAMMENOU et al., 2023). High concentrations of heavy metals (such as Pb, As, Hg and Cd), generated by their intensified use in industrial processes, pose a major threat to public health. In this context, bioremediation is emerging as a sustainable, affordable and environmentally friendly solution based on the use of microorganisms, green plants or enzymes to remove heavy metals from contaminated environments (GAUR et al., 2014). There is a growing global need to use plants to restore the natural environment. Research indicates that plants contribute to the restoration of ecosystems mainly through their metabolic processes, as well as by working with various micro-organisms. During remediation, the ability of plants to purify is conditioned by factors such as light, stomatal aperture, temperature and microbial species diversity (WEI et al., 2021).

The rapid expansion of industry, coupled with human activities such as the intensive use of chemicals in agriculture, the burning of fossil fuels and the inadequate management of sewage sludge, has led to the serious contamination of soils and water resources with heavy metals. These elements, being resistant to biological degradation, persist in the environment and require remediation methods to prevent their spreading in the ecosystem and to allow their effective disposal. Bioremediation, which is based on the action of micro-organisms, is one such solution, which develop various mechanisms to reduce the effects of contamination. Heavy metal pollution is a major stress on human health, flora, fauna and other forms of life. In this context, a thorough understanding of the processes involved and of remediation alternatives is essential to ensure effective and economically viable solutions (KAPAHI et al., 2019).

Among the many methods adopted to reduce heavy metal pollution, bioremediation is considered a sustainable and cost-effective technology. Bioremediation relies heavily on bacteria, in addition to other microorganisms and plants. The inherent and adaptive mechanisms developed by bacteria to defend themselves against metal toxicity include bioadsorption/biosorption, bioaccumulation, bioprecipitation, and bioleaching (SREEDEVI et al., 2022).

The aim of this manuscript is to analyze the research existing in the Web of Science on the topic of soil degradation in the presence of heavy metals, the mechanism that are associated with plants and microorganisms for their removal and their potential disturbance on grassland species and biomes.

TECHNIQUES AND PLANT-MICROORGANISM INTERACTION FOR HEAVY METALS REMOVAL

Bioremediation is a cost-effective solution for removing pollutants from the environment (LATA et al., 2019). This strategy involves the use of living microorganisms and plants (through the process of phytoremediation) to extract heavy metals (figure 1).

Bioremediation and phytoremediation (figure 2) are among the most effective strategies used for environmental restoration (CABRAL et al., 2015). In this context, arbuscular mycorrhizal fungi (AMF) represent the most valuable type of mycorrhizae involved in phytoremediation processes. They are commonly found in polluted soils and research indicates that they enhance plant resistance to high levels of toxic elements in small amounts. Similar to other organisms, plants have multiple mechanisms through which they can neutralize the harmful effects of heavy metals (KUSHWAHA et al., 2015).

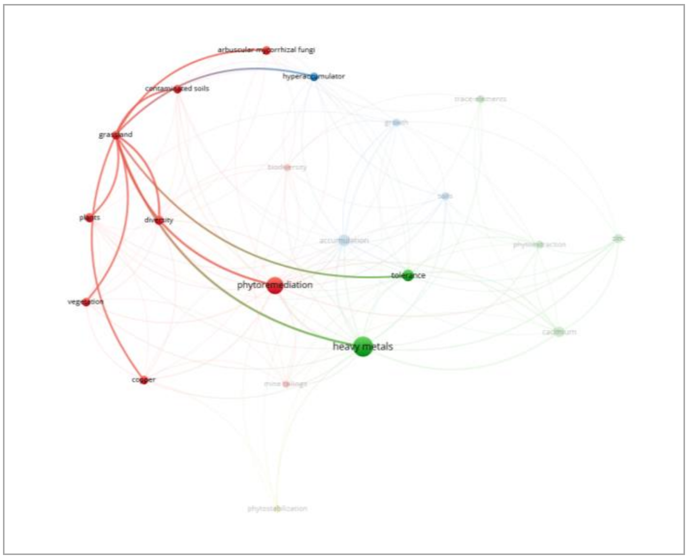

Fig. 1. The relation between grasslands and phytoremediation of heavy metals (developed with VOSviewer)

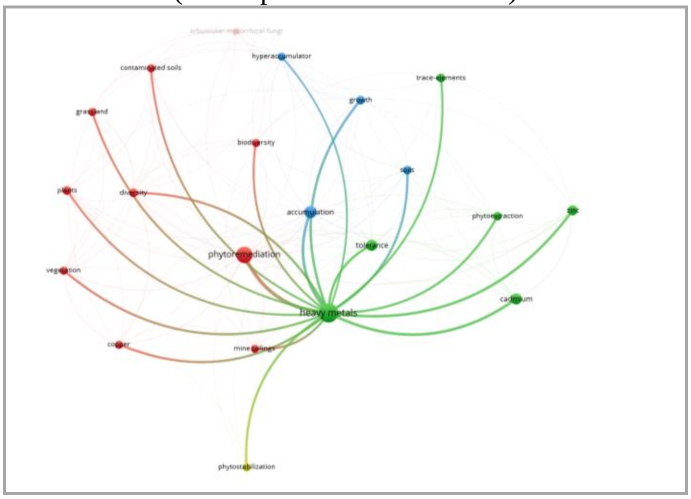

Fig. 2. The impact of heavy metals on plant species from grasslands (developed with VOSviewer)

These mechanisms include limiting metal absorption by associating with mycorrhizae, fixing them in the cell wall or through root excretion, removing metal ions from the plasma membrane, complexing them with phytochelatins and metallothioneins, and isolating them in vacuoles. Phytoremediation is a modern and promising technology based on the use of plants, together with microorganisms in the rhizosphere, to remove pollutants from contaminated soils.

Plants develop various strategies (figure 3) to cope with the toxicity caused by heavy metals (COBBETT et al., 2001). One of these mechanisms consists of neutralizing metals by binding them to certain peptide compounds known as phytochemicals. Advances in molecular genetics have provided valuable information about the processes involved in the synthesis of these compounds. The use of plants to clean soils contaminated with heavy metals, a process called phytoextraction, has many advantages, but the efficiency of this method is not yet high enough to be economically viable.

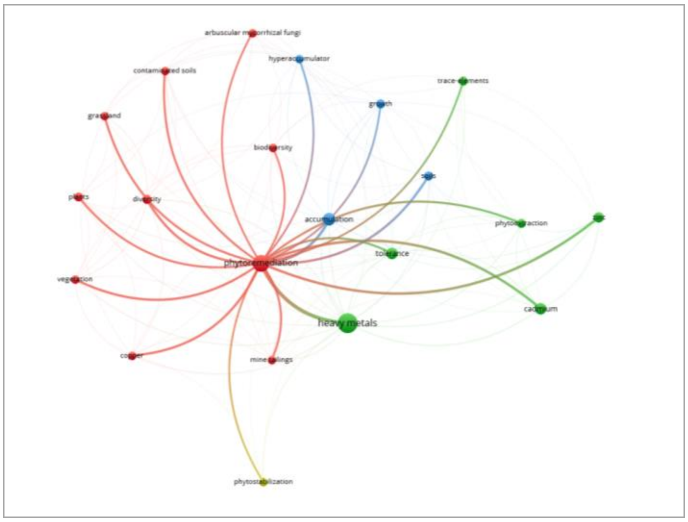

Fig. 3. Plant strategies for heavy metals removal (developed with VOSviewer)

A known way to increase the efficiency of phytoextraction is to inoculate the rhizosphere of plants with beneficial microorganisms (WOOD et al., 2016). Plants can remove over 95% of pollutants in soils. The selection of suitable species depends on the type of contaminants in the soil. The mechanisms by which phytoremediation occurs include uptake, internal transport, stabilization and volatilization of pollutants by plants (ZHU et al., 2024).

THE IMPACT OF HEAVY METALS ON BIOMES AND THE REMOVAL AIM

Heavy metal pollution is a serious problem that can have long-term effects on human health and the environment (NNAJI et al., 2023). Therefore, it is essential to implement effective methods for removing and remediating these pollutants in order to protect human health and ecosystems (figure 4, 5). Traditional methods of heavy metal removal, such as chemical treatments or physical methods, can be costly and have negative effects on the environment. In contrast, the use of plants and microorganisms in the bioremediation of metal-contaminated environments has proven to be an effective solution based on the accumulation and/or detoxification of metals. This approach is economical, versatile, efficient, and environmentally friendly.

The use of plants, either directly or indirectly, to clean contaminated soil or water is called phytoremediation (ARTHUR et al., 2005). This technology has become a more affordable, non-invasive, and widely accepted method for removing pollutants from the environment. The use of plants together with associated microorganisms to remove, isolate, inactivate, or decompose hazardous pollutants from the environment, a process generally known as phytoremediation, is gaining increasing interest (VANGRONSVELD et al., 2009).

The effectiveness of phytoremediation as a remediation technology depends on several factors, including the degree of soil contamination, the availability and accessibility of pollutants to microorganisms in the rhizosphere and their absorption by roots (bioavailability), as well as the ability of the plant and associated microorganisms to intercept, absorb, accumulate, and/or break down these contaminants.

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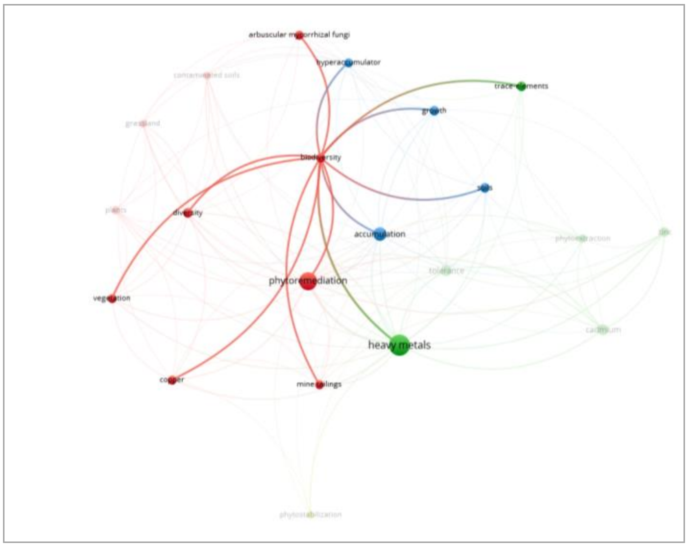

Fig. 4. The role of phytoremediation in restoring biodiversity (developed with VOSviewer)

Phytomanagement aims to use valuable non-food crops to reduce environmental and health risks caused by pollutants and to restore ecosystem services. Suitable plant species must be tolerant to contaminants, limit their transfer into the food chain, and produce commercial biomass efficiently. Due to Miscanthus ability to fix inorganic contaminants in the root system and facilitate the decomposition of persistent organic pollutants in the soil, these plants are ideal for phytostabilization and phytodegradation. Miscanthus × giganteus, with its high lignocellulose content, is a promising crop for the bioeconomy, particularly for the biorefining and bioenergy industries. Growing this species on contaminated or marginal land offers a viable solution to avoid changing the use of agricultural land and helps resolve controversies related to competition between food and biofuels (NSANGANWIMANA et al., 2019).

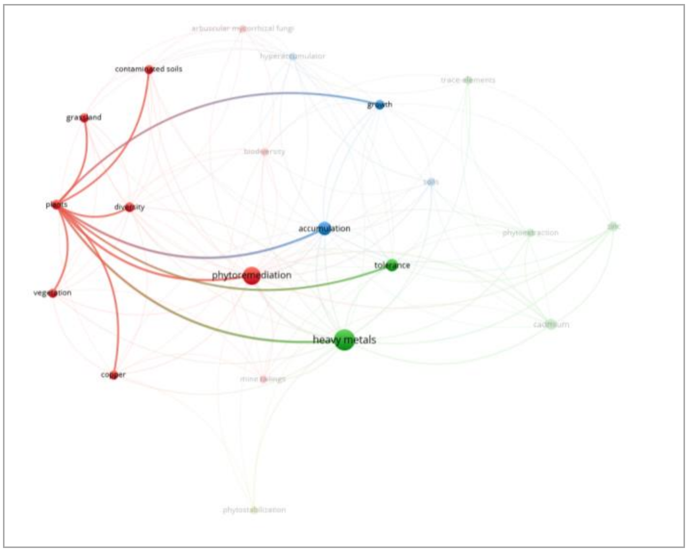

Fig. 5. Plant abilities to survive during phytoremediation processes (developed with VOSviewer)

THE IMPORTANCE AND IMPACT OF MICROBIAL RESOURCES IN BIOREMEDIATION OF POLLUTED GRASSLANDS

Various human activities, such as mining, intensive agricultural practices, and industrialization, have long-lasting negative effects on the environment (TIWARI et al., 2018). These processes contribute to the accumulation of heavy metals in soil, water, and air. Promisingly, the use of microorganisms as an alternative solution to increase plant tolerance to heavy metals has begun to attract increasing interest. The relationship between plants and soil microorganisms plays an essential role in the adaptation of vegetation to metal-rich environments, thus opening up new perspectives for applying this interaction to increase plant resistance to metal contamination (figure 6).

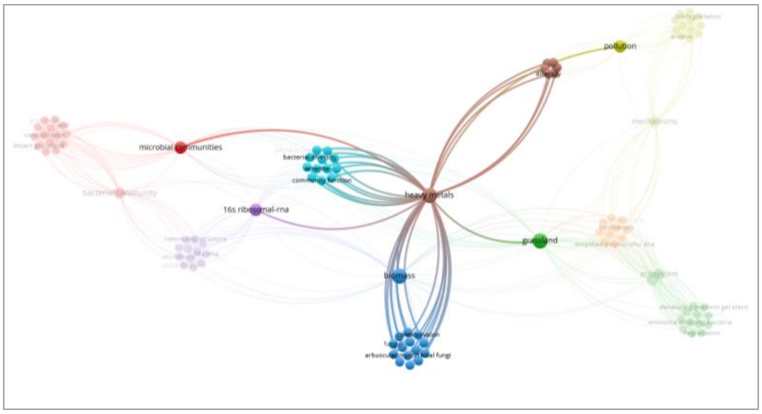

Fig. 6. The general impact of heavy metals on grassland plants and microorganism (developed with VOSviewer)

Abiotic stress factors, such as drought, salinity, heavy metals, temperature fluctuations, and ultraviolet radiation, negatively influence plant growth and development, leading to decreased production (KHAN et al., 2021). These factors directly affect the rhizosphere, which has a significant impact on root system development and, implicitly, on the overall condition, health, and yield of the plant. In the rhizosphere, plants are in constant interaction with a multitude of microorganisms.

Over time, numerous cases of arsenic poisoning have been reported globally, and the highly toxic effects of this element on humans, plants, and animals are well known (WILLIAM et al., 2023). Human activities that contribute to soil and water contamination with arsenic, together with its persistence and toxicity, make arsenic a pollutant of great interest and concern. In this context, bioremediation using microorganisms has emerged as one of the most effective methods due to its safety, reliability, and sustainability (figure 7).

These pollutants negatively affect the health of plants, animals, and humans. In addition, they contribute to the destruction of microbial populations in aquatic and terrestrial environments, making intervention through remediation methods necessary. Bioremediation consists of using biological organisms, such as plants and microorganisms (figure 8), to eliminate or diminish the impact of pollutants on the environment (AYILARA et al., 2023). For this purpose, various groups of bacteria, fungi, and algae have been used to help clean up different types of pollutants.

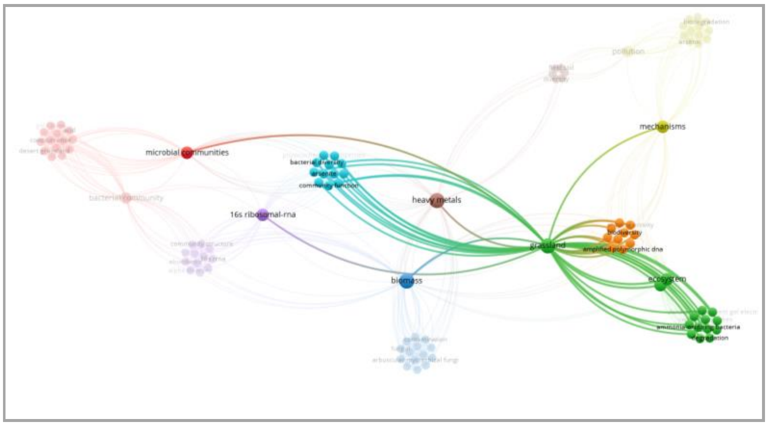

Fig. 7. The integrated concept of plant-microorganism survival and removal of heavy metals in grasslands (developed with VOSviewer)

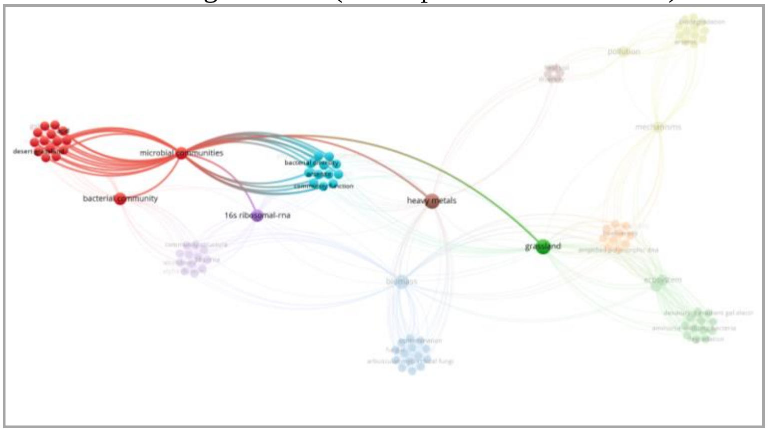

Fig. 8. Microbial abilities involved in heavy metals removal from grasslands (developed with VOSviewer)

High concentrations of heavy metals and non-essential metalloids (arsenic, cadmium, and lead) in soils and irrigation water pose a threat to the environment, food safety, and human and animal health (GONZALEZ HENAO et al., 2021). Microbial bioremediation has become a promising strategy for reducing these concentrations, thanks to the proven ability of microorganisms, especially bacteria, to capture and transform these toxic substances.

Environmental pollution caused by hazardous waste, organic pollutants, and heavy metals has had a negative impact on the natural ecosystem, ultimately affecting human health (OJUEDERIE et al., 2017). Toxic metals can accumulate in agricultural soil and enter the food chain, posing a serious threat to food security. In this context, bioremediation is proving to be an environmentally friendly and effective method of restoring environments contaminated with heavy metals, using the natural biological mechanisms of microorganisms and plants to eliminate hazardous pollutants.

THE SIGNIFICANCE OF FUNCTIONAL MICROBAIL COMMUNITIES IN RHIZODEGRADATION

The significant impact of microorganisms (figure 9) on crop growth, stress resistance and ecological restoration has attracted increased interest due to the complex interaction between these micro-organisms and plants (IQBAL et al., 2023). Various microbial groups, including bacteria, fungi, archaea and viruses, have been shown to stimulate the production of growth-supporting hormones, activate stress response mechanisms and improve nutrient availability through fixation and solubilization processes.

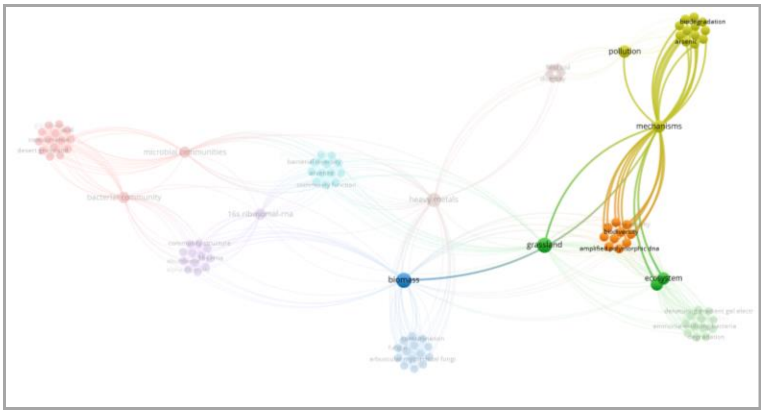

Fig. 9. Microbial mechanism in the removal of heavy metals from grasslands (developed with VOSviewer)

Rhizoremediation, a specific form of phytoremediation involving both plants and microorganisms in the rhizosphere, can occur naturally or be stimulated by the intentional introduction of certain organisms (figure 10). During this process, plant roots release exudates that promote and stimulate the development and activity of the microbial community in the rhizosphere. As a result, pollutants are effectively degraded (SARAVANAN et al., 2020).

Plant-assisted bioremediation, also known as phytoremediation, is a promising method for in situ treatment of contaminated soils (figure 11). To improve these processes, a thorough understanding of the complex interactions in the rhizosphere is needed (WENZEL, 2009). Literature reviews indicate that the bioavailability of pollutants in the rhizosphere of crops used in phytoremediation is essential for the development of effective and predictable technologies. The limitations related to the bioavailability of pollutants can be overcome by creating plant-microbial consortia able to mobilize metals and metalloids by altering the rhizosphere pH (e.g. by co-cultivation with Alnus species) and by releasing ligands, or by increasing the bioavailability of organic pollutants through the secretion of biosurfactants. In addition to this limitation, another major obstacle is the lack of competitiveness of inoculated microbial strains (especially degradative ones) under field conditions.

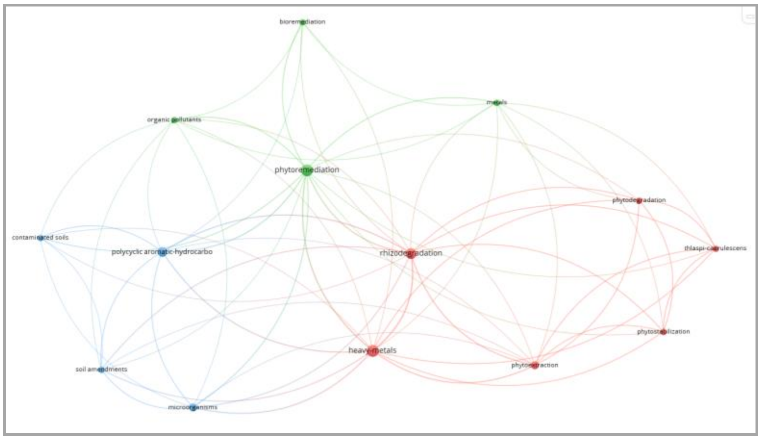

Fig. 10. Root-microorganism interaction for rhizodegradation of pollutants (developed with VOSviewer)

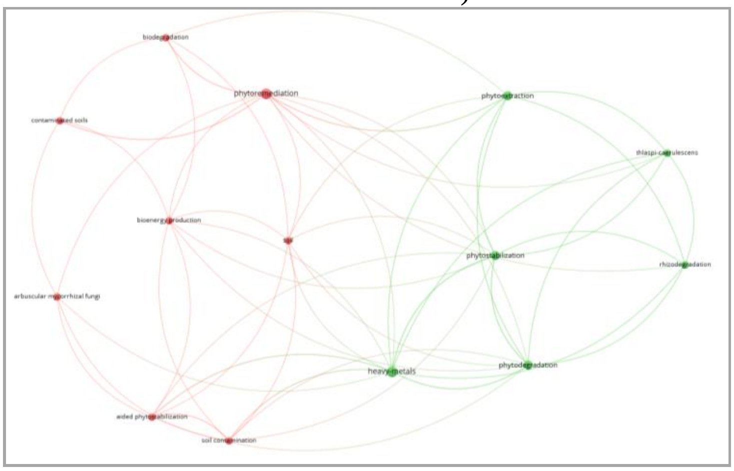

Fig. 11. The synergy between plants and microorganism in phytoremediation and phytostabilization (developed with VOSviewer)

Microorganisms have a complex role that includes partial biodegradation of pollutants, stimulating plant growth and sustaining nutrient supply (CHOJNACKA et al., 2023). Plants produce root exudates that help micro-organisms to degrade organic pollutants and stimulate their growth. Pollutants are taken up by plants through the root system, a process that can be further supported by endophytic micro-organisms. The collaboration between these three components generates a synergistic effect that improves the efficiency of rhizodegradation supported by functional materials, a more efficient method than the isolated use of micro-organisms, phytoremediation or functional materials. The combination of physico-chemical (functional materials) and microbiological (bacteria and fungi, rhizosphere, symbiotic or non-symbiotic) methods, supported by hyperaccumulator plants, is a promising strategy for reducing chemical pollutants in soil.

CONCLUSIONS

The current context of soil pollution with heavy metals require more sustainable approaches based on both plants and microorganism mechanisms.

Both bioremediation and phytoremediation are among the most effective strategies used for environmental restoration, and the use of microorganism in plant rhizosphere increase the efficiency of phytoremediation.

The interaction between plants and soil microorganisms plays an essential role in the survival of vegetation to polluted environments.

Rhizoremediation represent a specific form of phytoremediation involving microorganisms that possess the ability of partial biodegradation, plant-growth promotion and nutrient supply increases.

The use of plant-microorganism interaction opens new perspectives for the development of more efficient bioremediation techniques.

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FORAGE PRODUCTIVITY OF SOME SMOOTH BROMEGRASS (*Bromus inermis* Leyss.) CLONES

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Abstract

The aim of the research was to determine the feed production potential of some smooth brome clones (Bromus inermis Leyss.) *in the silvostepa area. The research was conducted during the period 2022-2024, at the Research and Development Station for Meadows (RDSM), Vaslui (46°40' - 36°10' north latitude and 27°44' - 20°40' east longitude). 25 Smooth brome sources were used as initial material in the research. The experiment was conducted as a completely randomized block design in three repetitions. In this research, the production of dry matter of this species in the years 17, 18, and 19 vegetation, respectively, under the conditions of pedoclimation of the area of experimentation. The results showed that differences of statistical significance were obtained between the variants taken in the study, in the three years taken in the study. The best-performing variants were the* $V_{8\ B1CL8}$ *variants in the 17th year of vegetation and the* $V_{11\ B1CL11}$ *in the 18th and 19th years. These high-yielding clones can be used as parents in polycross to develop synthetic varieties.*

Keywords: grassland, pasture, meadow, green mass, perennial, production.

INTRODUCTION

Maintaining the productive potential of temporary grasslands at the highest level can be achieved only if they are used in their composition species with productive potential, valuable species, application of fertilizers and their rational use (DEAK *et al.*, 2009; HANCOCK, 2011). The smooth brome is adapted to colder climates, resistant to drought and extreme temperatures (UNDERSANDER *et al.*, 1996; KOSTOPOLULU and KARATASSIOU, 2016). Thanks to the highly developed root system, the unassisted obsiga has high resistance to extreme temperatures and drought (TURK *et al.*, 2015). The technology of growing the seed batches of fodder species is different from the technology of fodder production, with a tendency to improve the morphological peculiarities of seed production and seed quality indices (ENE and MOCANU, 2016; SAMUIL *et al.*, 2012; VACARCIUC *et al.*, 2023).

Bromus inermis is an important species due to its high drought tolerance and ability to adapt to new environmental conditions (RAAWE, 2004).

Smooth brome is characterized by a unique morphology of the aerial part. Vegetative shoots are predominant and similar to generative shoots; they are formed from a high percentage of leaves, which contributes to high feed production as well as high quality of the resulting feed (KOZŁOWSKI *et al.*, 1992; MACKIEWICZ- WALEC *et al*. 2024). Understanding how plants adapt to drought is crucial for predicting the impact of climate change on grasslands composition and diversity (KROEGER and OTFINOWSKI, 2024).

MATERIAL AND METHOD

The purpose and objectives of the research carried out at the Research and Development Station for Meadows Vaslui were represented by the forage productivity of some smooth bromegrass (*Bromus inermis* Leyss.) clones. The research was carried out during the period 2022-2024, within the Research and Development Station for Meadows (RDSM), Vaslui (46°40'-36°10' north latitude and 27°44'-20°40' east longitude). The experience was established in 2006, it consists of 25 variants (individual plants), in 4 repetitions, each variant having a length of 6 m and a width of 1 m.

(green - optimal period; orange - water deficit period)

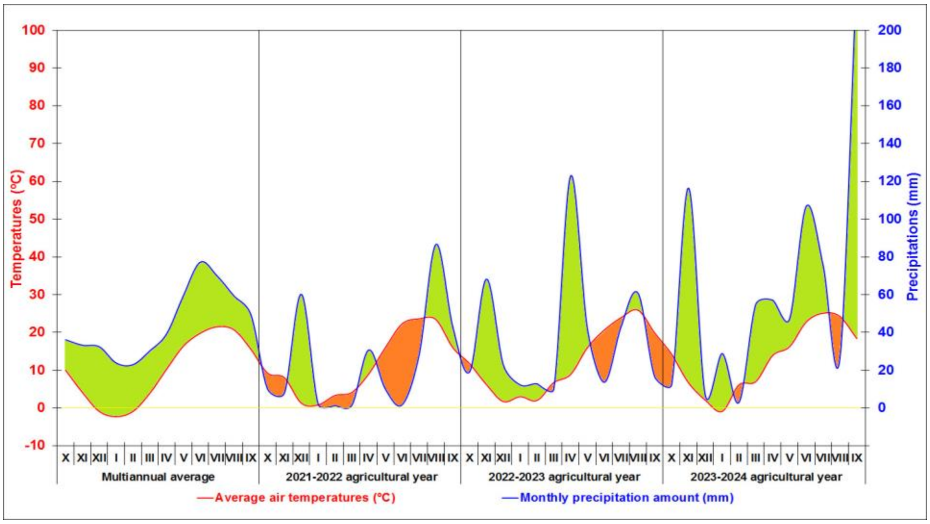

Figure 1. 2021-2024 Agricultural period climadiagram

In the three years studied, only one cut was performed per year, the second cut being only one of cleaning. The time of harvesting the plants was when over 50% of the plants had flowered. Each variant was harvested and weighed, representing the amount of green mass (G.M.) A sample of 200 g G.M., dried at 65°C for 8 hours, then weighed. The climatic conditions of the experimentation period, namely 2022-2024. In the agricultural period 2022-2023, there were two dry years with recorded rainfall being half of the multiannual average. During the period from April to September, there was a precipitation deficit every month. The agricultural year 2023-2024 was marked by high rainfall. Although the rainfall was above the multiannual average, there were also periods of water stress and uneven distribution (figure 1). The results were statistically interpreted by analyzing variance and calculating last significant differences (LSD).

RESULTS AND DISCUSSIONS

Productivity data are shown in Tables 1 and 2.

The production yield obtained differences of statistical significance in year 17 of vegetation, 2022 (table 1), values ranging from 3035 kg•ha^{-1} to variant V_{15} B2CL3 and 4897 kg•ha^{-1} to variant V_{8} B1CL8, with 1477 kg•ha^{-1} more than the blank variant.

Table 1

Plant production at first cut in the 17, 18, and 19 years of vegetation at *Bromus inermis* Leyss.

Variant	Production *kg•ha^{-1} D.M.*		
	Year 17 (2022)	**Year 18 (2023)**	**Year 19 (2024)**
V_{1} B1CL1	3443	6935 ^{ooo}	5997 ^{ooo}
V_{2} B1CL2	3555	8417	6405
V_{3} B1CL3	4219 ***	8946	6874
V_{4} B1CL4	4557 ***	7624 ^{ooo}	6741
V_{5} B1CL5	3982 ***	7558 ^{ooo}	6611
V_{6} B1CL6	3741 **	8222	6378
V_{7} B1CL7	4257 ***	9600 ***	7116 *
V_{8} B1CL8	4897 ***	7447 ^{ooo}	6583
V_{9} B1CL9	3823 ***	8893	8996 ***
V_{10} B1CL10	3595	9104 *	7404 ***
V_{11} B1CL11	4285 ***	10303 ***	9622 ***
V_{12} Olga control	3420 $^{C.}$	8529 $^{C.}$	6673 $^{C.}$
V_{13} B2CL1	3392	7553 ^{ooo}	6052 ^{oo}
V_{14} B2CL2	3541	8130	6210 ^{o}
V_{15} B2CL3	3035 ^{ooo}	8811	6750
V_{16} B2CL4	3700 *	8409	7637 ***
V_{17} B2CL5	3245	7778 ^{oo}	7129 *
V_{18} B2CL6	3710 **	8349	7280 **
V_{19} B2CL7	3272	7755 ^{oo}	6607
V_{20} B2CL8	3675 *	7653 ^{ooo}	6036 ^{ooo}
V_{21} B2CL9	3281	7940 ^{o}	6298 ^{o}
V_{22} Doina	3163 ^{o}	9556 ***	7300 **

V_{23} Doina		3156 ^{o}	7807 ^{oo}	7617 ***
V_{24} Doina		3792 ***	9096 *	6475
V_{25} Doina		3929 ***	8910	7260 **
LSD	***0.5%***	***213.9***	***461.6***	***364.8***
	0.1%	***285.3***	***615.5***	***486.5***
	0.01%	***371.5***	***801.5***	***633.5***

Of the 25 origins in the 17th year of vegetation, 16 variants exceeded the V_{12} control variant, achieving higher yields by up to 43%. In the 18th year of vegetation, 2023 (table 1.), values were obtained between 6935 kg•ha^{-1} D.M. at V_{1} B1CL1 and 10303 kg•ha^{-1} D.M. at V_{11} B1CL11 variant, with 1774 kg•ha^{-1} D.M. more than the control variant. Significant statistical significance was obtained in V_{10} B1CL10, V_{24} Doina, and very significant statistical significance in V_{7} B1CL7, V_{11} B1CL11, and V_{22} Doina variants. In 2023, only 9 variants exceeded the V_{12} control variant, up to 20 % more. The year 18 being also the year in which the production of the d.m was superior, the control variant V_{12} obtained 8529 kg•ha^{-1} while in the years 17 and 18 vegetation the obtained quantities were much lower, 3420 kg•ha^{-1}, respectively 6673 kg•ha^{-1} D.M.

Table 2

Average production at first cut in the 17, 18, and 19 years of vegetation at *Bromus inermis* Leyss.

Variant	**Production kg•ha^{-1} D.M. average 2022, 2023, 2024**	**Difference**		**Significance**
		%	**kg/ha**	
V_{1} B1CL1	5459	87.9	-749	ooo
V_{2} B1CL2	6126	98.7	-81	
V_{3} B1CL3	6680	107.6	473	*
V_{4} B1CL4	6307	101.6	100	
V_{5} B1CL5	6050	97.5	-157	
V_{6} B1CL6	6113	98.5	-94	
V_{7} B1CL7	6991	112.6	784	***
V_{8} B1CL8	6309	101.6	102	
V_{9} B1CL9	7237	116.6	1030	***
V_{10} B1CL10	6701	108.0	494	*
V_{11} B1CL11	8070	130.0	1863	***
V_{12} Olga control	6207	100	C.	C.
V_{13} B2CL1	5666	91.3	-541	o
V_{14} B2CL2	5960	96.0	-247	
V_{15} B2CL3	6199	99.9	-8	
V_{16} B2CL4	6582	106.0	375	
V_{17} B2CL5	6051	97.5	-156	
V_{18} B2CL6	6446	103.9	239	
V_{19} B2CL7	5878	94.7	-329	
V_{20} B2CL8	5788	93.2	-419	o
V_{21} B2CL9	5840	94.1	-367	

V_{22} Doina	6673	107.5	466	*
V_{23} Doina	6193	99.8	-14	
V_{24} Doina	6454	104.0	247	
V_{25} Doina	6700	107.9	493	*
	LSD	***0.5%***	***411.8***	
		0.1%	***549.1***	
		0.01%	***715.0***	

In the 19th year of vegetation, 2024 (table 1), the obtained values were between 5997 kg•ha^{-1} D.M. at $V_{1\ B1CL1}$ and 9622 kg•ha^{-1} D.M. at $V_{11\ B1CL11}$. This year, too, values with positive statistical assurance were obtained for V_9, V_{10}, V_{11}, V_{16}, and V_{23} variants, obtaining very significant statistical significance. In this field of the 25 variants, 12 proved to be superior to the control variant (V_{12}), the production varied depending on the vegetation year and especially the climatic conditions of the year. In the three years of research (table 2.), the average production ranged from 5459 kg•ha^{-1} to $V_{1\ B1CL1}$ and 8070 kg•ha^{-1} to $V_{11\ B1CL11}$. The results obtained in the three years of production (table 2), show that this species achieves an important production of s.u. and in the 17-19 years of vegetation, these varied depending on the climatic conditions of the year.

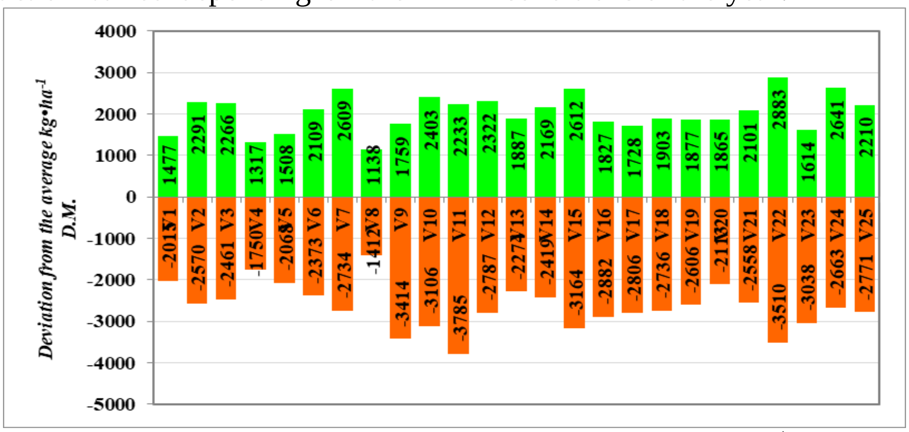

Figure 2. D.M. Production deviation from the average (kg•ha^{-1} D.M.)

Compared to the average over the three years of production (17, 18, and 19 vegetation), the positive and negative deviations (figure 2.) were recorded at the V_8, V_4, V_1, and V_{20} variants. The positive and negative deviations with the highest amplitude were recorded in the V_{22}, V_{11}, and V_{24} variants. The most important variants being V_8 and V_1, they are stable according to the climatic conditions of the last three years of vegetation, the obtained production did not have an increase or decrease compared to the V_{22} variant, where the oscillations were very much more in these years of production.

Assessing origins requires the determination of quantitative traits, as hereditary traits are a source of genetic diversity and can be easily modified under environmental conditions. The creation of new valuable varieties is possible due to the large range of variability within the genetic resources of *Bromus inermis* Leyss.

CONCLUSIONS

In this research, the dry matter. production obtained differences with statistical assurance. In 2022, year 17 vegetation productions were 3035 kg•ha^{-1} D.M. and 4897 kg•ha^{-1} D.M., in 18 year vegetation, the obtained productions ranged between 6935 kg•ha^{-1} and 10303 kg•ha^{-1}, and in 19 year vegetation, the production was between 5997 kg•ha^{-1} D.M. and 9622 kg•ha^{-1}. The highest yields in the three years studied were obtained at the V_8 variant, in the 17th year of vegetation, and at V_{11}, in the 18th and 19th years of vegetation. This study shows that this species, *Bromus inermis*, is a resistant species with high perennial, drought-tolerant, obtaining productions and in the 17-19 years of vegetation.

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THE ADAPTABILITY OF THE GALLOWAY BREED TO ROMANIAN PASTURES: A SYSTEMATIC ANALYSIS OF ZOOTECHNICAL POTENTIAL – A REVIEW

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Abstract

In the current context of European agriculture, marked by economic pressures, increasingly stringent sustainability requirements, and the need for efficient use of agroecological resources, it is essential to select cattle breeds adapted to diverse soil and climate conditions for the sustainable development of the livestock sector. This paper analyzes the potential benefits of using the Galloway breed in extensive cattle farming systems, particularly in Romania's hilly and mountainous regions, where significant areas of natural and semi-natural pastures remain underutilized. The Galloway breed originates from southwestern Scotland and is characterized by hardiness, remarkable adaptability to harsh climatic conditions, efficiency in utilizing low-quality pastures, and docile behavior. These characteristics facilitate extensive management. Their double coat provides thermal insulation, enabling the animals to overwinter outdoors and reducing the need for technological investments. Furthermore, the breed's productive performance reflects favorable economic potential under low-input conditions. International case studies from Scotland, Canada, and Luxembourg demonstrate the use of Galloways in producing high-quality meat and in ecological conservation and restoration projects for degraded habitats through controlled grazing and invasive vegetation management. In Romania, experimental results from the Cojocna Educational Farm (USAMV Cluj-Napoca) confirm the breed's superior performance under extensive grazing conditions compared to other rustic breeds in similar systems. In conclusion, integrating the Galloway breed into extensive farms in Romania can increase the resilience of agroecosystems, sustainably utilize marginal land, and economically diversify farms in areas with low livestock-pastoral potential.

Keywords: *Galloway breed, permanent grasslands, ecological adaptability, low technological requirements, extensive grazing*

INTRODUCTION

In the current context of European agriculture and the growing need for sustainable and robust farming systems that are adapted to local conditions, selecting cattle breeds that can efficiently use pastures is essential. Romania has significant potential in terms of natural and semi-natural pastures, especially in hilly and mountainous regions. These resources can be used efficiently through extensive livestock farming; however, this requires rustic breeds that are well-adapted and have low technological requirements. The permanent grasslands in our country cover approximately 4.9 million hectares. Of this area, 68% is used as grassland for pastures, while the remaining 32% is used for the production of hay. Approximately 79% of these grasslands (about 3.8 million hectares) are located in hilly and mountainous areas, which have significant livestock potential but are often not properly exploited (Rotar, I. and Vidican Roxana, 2003; Samuil, C. and Vîntu, V., 2012; Mocanu, V. et al. 2021; Cojocariu Luminita, 2022). At the same time, the cattle sector in Romania is experiencing a downward trend. According to data from the National Institute of Statistics (INS), there were 1,814,700 head of cattle in 2023, compared to 1,833,700 in the previous year. This reflects a modest but steady decline in interest in this species (https://insse.ro). In this context, growth strategies must be rethought to include breeds that are better adapted to current conditions and more efficient in extensive systems. In relation to this topic, the Galloway breed, which originates from the harsh regions of Scotland, is a subject that is increasingly being addressed in the specialized literature because it is considered a model of adaptability in extensive systems. This hornless breed has a compact body and a double coat that protects it from cold and moisture (Pruitt, 2004). Its ability to utilize poor-quality pastures while maintaining a constant level of productive performance makes the Galloway breed a viable alternative for restoring the hilly and mountainous regions of Romania under conditions of increasing economic and ecological pressure (https://www.gallowaybeef.co.uk).

Against this background, the aim of this paper is to review the literature on the use of the Galloway breed in extensive cattle farming systems. The focus is on the sustainable use of pastures in Romania, and the main aspects related to the productive performance, ecological impact, and economic efficiency of this breed are highlighted.

REGARDING THE GALLOWAY BREED

Origin and Selection

The Galloway breed originated in the Galloway region of southwestern Scotland and was developed before the 17th century. These cattle are polled (hornless) and adapted to harsh conditions, such as hilly terrain and a wet, cold climate. They have a dense coat with a thick outer layer and an insulating inner layer, which allows them to winter outdoors without special shelter. The evolution of native Scottish Celtic breeds, of which the Galloway is one of the oldest, was shaped by natural selection until the 19th century, when they began to mix with other breeds. Initially, color variations (black, reddish, brindled, and sometimes white spots) were common. However, selection favored the polled line with a black coat until the 19th century when other color varieties (dun and red) were also recognized in the registry.

Selection and Development

In 1862, a "Polled Herd Book" was published, including the

Galloway breed alongside the Angus breed and others. The "Galloway Cattle Society of Great Britain and Ireland" was then established between 1877 and 1878. The society began to strictly record the breed's genealogy and standards (https://www.thecattlesite.com). Initial registrations focused on black specimens, but over time, dun and red varieties were also permitted. In 1878, the Galloway breed started its own separate herd book.

The process of selection focused particularly on individuals displaying superior traits characteristic of the Galloway breed, such as:

1. rusticity and adaptability, including a dense coat, tolerance to harsh climates, and the ability to graze on marginal land;

2. natural selection for meat production, including fine marbling and a well-balanced carcass obtained directly from pasture;

3. maternal qualities and longevity: cows have easy calvings and vigorous calves, and maintain reproductive performance until 15 – 17 years of age.

4. polled and docile: the breed is naturally hornless, and the temperament is normally calm (https://www.gallowaybeef.co.uk).

The society and herd book, established in 1877–1878, have played a fundamental role in maintaining the breed's purity, promoting standards, and supporting economic growth in extensive farming systems.

Table 1

The main characteristics of the Galloway breed

Category	**Characteristics**
Origin	Southwestern Scotland - Galloway Region
Breed type	Meat (cattle specialized for meat production)
Size	Medium
Adult weight	Cows: 500–600 kg; Bulls: 800–1000 kg
Conformation	Compact, well-muscled, deep chest
Presence of horns	Polled (naturally hornless)
Coat color	Black (dominant), red, dun; Belted Galloway has a white belt across the trunk
Coat structure	Double: thick outer coat and dense (thermo-insulating)
Maternal aptitude	Strong maternal instinct, easy calving, high reproductive longevity
Average daily gain	650–700 g/day (in extensive systems)
Slaughter yield	58–60 %, with fine marbling of the meat
Adaptability	Excellent for grazing in harsh climatic conditions and on low-quality pastures
Recommended system	Extensive, semi-extensive, organic, conservative (rewilding)
Temperament	Calm

Galloway Breed for Sustainable Grazing Systems

The Galloway breed is used successfully in extensive grazing systems on multiple continents, including in cold, wet areas and in temperate climates. This is due to the breed's hardiness, excellent grazing ability, and superior meat quality. Its consistent performance under various climatic and geographical conditions makes it a viable option for integrating into grazing systems in Romania, particularly in hilly and mountainous regions.

Belted Galloway cattle in ecological conservation in Scotland — Case Study

The native Belted Galloway breed is increasingly being integrated into ecological restoration projects in Scotland due to its adaptability to extensive grazing and its ability to maintain diverse vegetation mosaics. One significant example is the landscape restoration project at Threave Estate in the Dumfries and Galloway region, which is coordinated by the National Trust for Scotland. In 2021, 14 Belted Galloway cattle were introduced to promote the natural regeneration of vegetation and develop more open and diverse semi-natural ecosystems (https:// www .nts.org.uk). Implementing GPS-assisted grazing (Nofence) enables precise management of grazing pressure, preventing overgrazing in certain areas and encouraging the return of native species (https://www.nofence.no/en). These practices have positively affected both spontaneous flora, including tall grasses, and fauna, particularly birds and pollinators (https://www.nts.org.uk). A report by NatureScot and the Scottish Land Commission confirms that grazing with Belted Galloway cattle has led to the "opening up of the floodplain" and supported "genuine natural regeneration" (https://www.thecattlesite.com). This Scottish model shows that selecting a local, hardy, and adaptable breed, such as the Belted Galloway, and integrating it into an ecologically managed grazing system can be a valuable tool in ecological restoration strategies and the redevelopment of degraded habitats.

The Galloway Breed in Canada: performance, grazing, and conservation

The Galloway breed, including the Belted and White Galloway varieties, plays an increasingly important role in Canadian extensive animal husbandry. Farms across the provinces are integrating this breed. Their adaptability to cold climates, feed efficiency, and selective grazing behavior make them suitable for sustainable commercial farms and ecological conservation projects on marginal lands.The Galloway breed was introduced to Canada in 1853, making it one of the oldest British breeds established on the North American continent (Shrestha, J.N and Hansen, C. 1998). Renowned for its double coat with a thick outer layer and insulating undercoat, the Galloway breed is ideal for the cold Canadian climate, eliminating the need for expensive winter shelter (Shrestha, J.N and Hansen, C. 1998).

According to tests carried out at the University of Guelph (https://lbcentre.com.au), Galloway meat is low in saturated fat and rich in omega-3 fatty acids. This meat is rated as being comparable to fish or poultry in terms of its health benefits.

Galloway grazing — extensive management in Canada

Canadian farms that use Galloway cattle typically employ an extensive rotational grazing system. In this system, animals are periodically moved between paddocks to avoid overgrazing and encourage vegetation regeneration. Due to their diverse and selective grazing behavior, Galloways can consume a wide range of plants, including tough grasses and perennial species, that more specialized breeds cannot (Cirebea, Mirela. 2020). These characteristics make Galloway cattle well-suited for restoring degraded pastures or controlling invasive vegetation in pasture. In regions of Alberta and British Columbia with marginal lands, Galloway farms maintain the ecological structure of the landscape through targeted grazing, positively impacting local biodiversity (https://www.galloway.ca).

Galloway in Europe

The Belted Galloway breed is used in many conservation grazing projects throughout Europe because it can adapt to harsh environments and graze indiscriminately.

Restoration of floodplains — Syr Valley, Luxembourg with Galloway

In the Syr Valley Reserve, Belted Galloways have been used to restore wetlands to their natural state. A study conducted from 2006 to 2009 shows that the cattle contributed to the habitat's structural development, enriched the spontaneous flora, and balanced the vegetation through "habitat development and habitat use" (Schaich et al., 2010).

Galloway in Romania

The Galloway breed has proven well-adapted to Romanian conditions and is suitable for extensive organic farms in Transylvania. It offers economic, zootechnical, and ecological advantages and is therefore recommended for utilizing marginal land and practicing sustainable farming. A study conducted at the Cojocna Educational Farm (USAMV Cluj) from 2023 to 2024 compared the Galloway breed to the Highland breed. The study showed that Galloway calves had an average daily gain (ADG) of 676.9 g/day, which was higher than the ADG of Highland calves 581.1 g/day, (Ranta Mirela and Mălinaș AnaMaria, 2024; Ranta et al., 2024). This result reflects the breed's excellent adaptability to extensive grazing with low-to-medium-quality feed and to the climate.

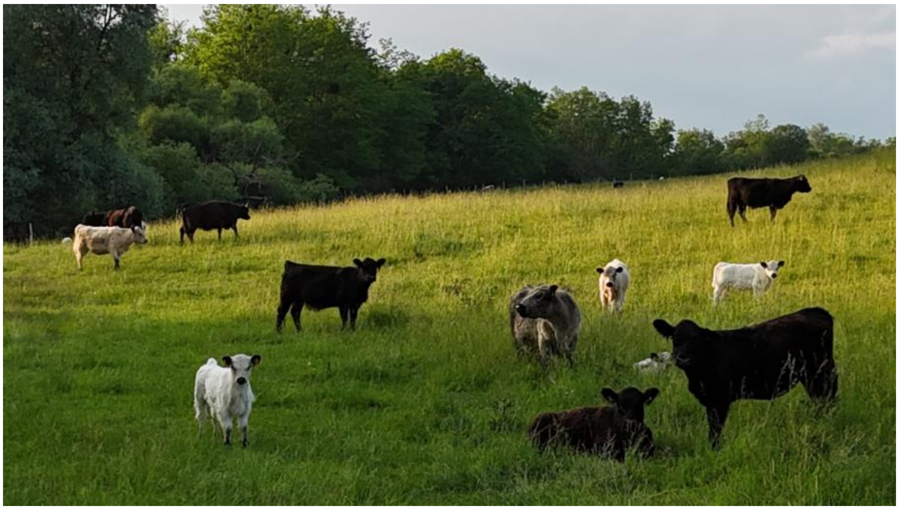

Fig. 1 Galloway on the grassland in Romania
(Source: original)

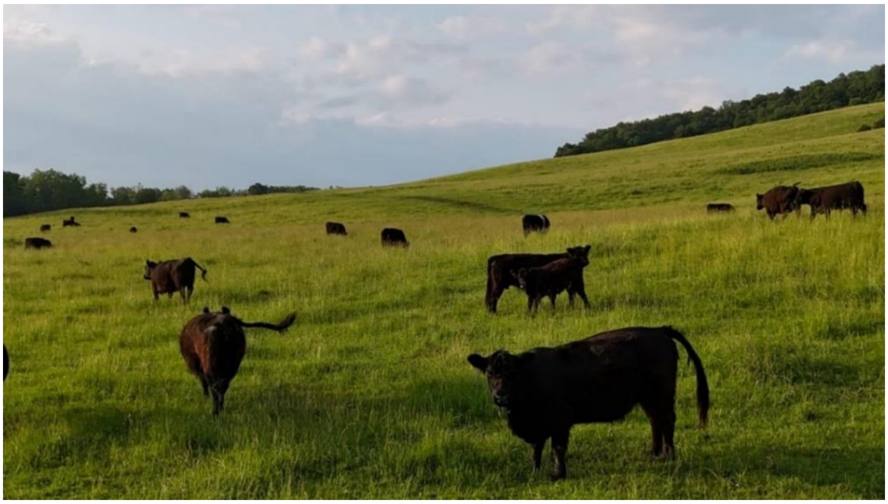

Fig. 2 Galloway grazing model in Veseud, Sibiu County
(Source: original)

CONCLUSION

The Galloway breed is a viable livestock resource for efficiently exploiting permanent pastures in Romania's mountainous and hilly regions. Due to its rusticity, adaptability to adverse environments, and minimal technological requirements, the breed is well-suited for extensive farming systems, particularly in regions with limited forage availability. Using the Galloway breed in these systems is justified by its ability to graze non-selectively, including consuming poorly palatable or invasive plant species.

Thus, the animals help maintain the compositional balance of the vegetation. Applying an optimal livestock density per hectare ensures uniform use of the land, preventing overgrazing and underutilization of certain areas. This breed's potential is especially valuable in mountain areas with abandoned or difficult-to-access pastures. Other specialized breeds cannot physiologically or behaviorally adapt to these environmental conditions or sustain viable production under extensive farming. Through constant grazing, Galloway cattle maintain, clean, and keep these lands in a functional state. This reduces the risk of vegetation invasion and supports the biodiversity specific to mountain ecosystems. At the same time, their ability to adapt to low temperatures due to their double insulating coat allows them to be raised outdoors during the cold season without specialized shelters. This significantly reduces technological costs and supports the viability of farms with limited resources. The breed's productive performance under extensive grazing conditions — evidenced by higher average daily gains than other rustic breeds — confirms its compatibility with Romanian agroecosystems.

RECOMMENDATION

There is potential to increase the use of Galloway cattle in hilly and mountainous regions of the country, particularly for the efficient use and restoration of natural pastures. Integrating this breed into maintenance plans for difficult-to-access or low-forage-value pastoral land contributes to agroecological balance, prevents habitat degradation, and maintains the characteristic floristic structure. As part of an integrated approach to biodiversity and ecosystem services in mountain areas, it is recommended that Galloway be included in agri-environmental measures, strategies to support low-input farms, and functional pasture conservation initiatives.

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HIGHLAND CATTLE – POTENTIAL FOR INTEGRATION AND ADAPTATION TO THE EXTENSIVE SYSTEM AT COJOCNA FARM

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Abstract

Considering that many pastures in Romania are not exploited to their full potential, the possibility of capitalizing on them by raising Highland cattle, which are capable of efficiently converting even low-quality grass into high-quality meat, was analyzed. The study, which focused on evaluating existing pastures and the adaptive behavior of the Highland breed in an extensive system, was carried out on the Cojocna farm, which belongs to USAMV Cluj. Pasture research covered 20 hectares of plot 11, which is part of the Natura 2000 site ROSCI0238 Suatu–Cojocna–Crairât. The goal was to evaluate the Highland breed's adaptability to the Cojocna Farm's specific soil and climate conditions by achieving the following objectives: 1) analyzing the effect of grazing with Highland cows on the ecological and agronomic value of Natura 2000 habitats; 2) determining the correlation between average daily gain (ADG) and the floristic composition of the pasture; 2) developing specific measures to improve pasture types; and formulating recommendations on technology for farming Highland beef cows in an extensive system. This research activity was conducted in 2023. The methodology included weighing calves according to the official performance control system (COP) to determine ADG, as well as geobotanical methods using the Braun-Blanquet scale to identify and characterize grassland types in two descriptive plots (PD1 and PD2).

The results show that the gains achieved fall within the performance parameter s specific to the Highland breed, despite the pastures being dominated by plant types such as Stipa capillata, - Carex humilis, and Festuca rupicola, which are only moderately tolerant of grazing. In this context, we recommend implementing a rational grazing system, clearing woody vegetation, and controlling toxic plants to ensure the pastures are exploited sustainably and efficiently.

Keywords: *Highland cattle, grassland, adaptability, average daily gain*

INTRODUCTION

Highland cattle are considered one of the oldest known pure breeds. They originated in the Highlands of Scotland. Over many centuries, it evolved through natural selection in harsh climatic conditions and marginal land. This process favored traits such as hardiness, longevity, fertility, pronounced maternal behavior, and adaptability to grazing in harsh conditions (Nota et al., 2024).

The breed was officially recognized when the Highland Cattle Society was established in 1884 and the first Herd Book was published in 1885. Since the 19th century, the breed has spread to various areas with severe climates, including Canada, the United States, and Germany (Svensk et al., 2023).

One of the most distinctive features of this breed is its double coat, which consists of a long, thick, oily outer layer that repels water and a thin, dense undercoat that provides thermal insulation. This adaptation enables the animals to remain outdoors year-round, even in low temperatures or high humidity (Nota et al., 2024; Sambraus, 2016).

Highland cattle have compact bodys with low centers of gravity and broad hooves adapted to muddy, rocky, or steep terrain. Their moderate weight and large hoof surface area result in low pressure exerted on the soil, reducing the impact on the vegetation layer and minimizing soil compaction (Pauler et al., 2022; Ranta & Mălinaș, 2024).

Highland beef is recognized for its low fat and cholesterol content, as well as its high ratio of omega-3 fatty acids and conjugated linoleic acid (CLA). Compared to intensively raised breeds, Highland beef has a higher protein, iron, and zinc content and a lipid profile that is favorable to human health (https://hyndmanbeef.com). This type of meat comes almost exclusively from extensive grazing, without the use of concentrates.

Highland cattle have adaptable feeding behaviors and a preference for mixed diets, including grass, herbaceous plants, and woody species or shrubs. Studies in forested areas of the Swiss and Italian Alps have shown that Highlanders consume 15-46% woody plants, such as *Alnus viridis*, *Rubus spp*., and *Fraxinus*. This helps control invasive species and maintain ecosystem balance (Svensk et al., 2023; Pauler et al., 2022).

In addition to their effect on clearing and compaction, Highlands contribute to biodiversity enhancement through seed transport (endo- and epizoochory) and by maintaining plant diversity in grasslands (Nota et al., 2024). In the current context marked by the transition to sustainable agriculture and biodiversity conservation, the Highlands are regaining the attention of farmers, ecologists, and researchers. Their ability to graze a wide variety of vegetation, including woody species, and to support the conservation of semi-natural habitats makes them a valuable asset in ecological pasture management similar to Galloway cattle (Ranta et al., 2024). This study aims to assess the adaptability of the Highland cattle breed within an extensive system, in the context of the specific soil and climate conditions of the Cojocna Farm. In this context, the following main objectives were followed: a) to analyze the impact of grazing with Highland cattle on the ecological and agronomic value of habitats included in the Natura 2000 site; b) to establish the correlation between average daily gain (ADG) and the floristic composition of the pastures used at the Cojocna Farm; c) formulation of specific measures to improve pasture types; d) development of a set of technological recommendations for the efficient exploitation of Highland cattle in extensive systems.

MATERIAL AND METHOD

The research was carried out at the Cojocna Farm, an educational and experimental station administered by the University of Agricultural Sciences and Veterinary Medicine in Cluj-Napoca. The farm is located in Cluj County, at an altitude of 369 m, in an area with a moderate temperate-continental climate, characterized by an average annual temperature of approximately 9 °C and average annual precipitation of approximately 860 mm.

The total grassland area is approximately 267 hectares. Some of these lands are part of the Natura 2000 site ROSCI0238 Suatu–Cojocna–Crairat, a protected area of community interest, recognized for its biodiversity specific to grassland ecosystems of high ecological value.

Data analysis

An area of 20 ha of grassland located within the Natura 2000 site was used for extensive grazing by a herd of 10 Highland beef cattle. The resulting stocking rate was estimated at 0.4–0.5 livestock units (LU)/ha. The farming system was unparceled, free-range, adapted to the ethology of the breed, which shows a marked preference for large, open spaces, an essential aspect in the context of biodiversity conservation and the maintenance of semi-natural habitats.

The growth performance of the calves was monitored in accordance with the Official Production Control (OPC) methodology, as part of an organized breeding program. The average daily growth (ADG) parameter was determined based on standardized calculations, using specific formulas for pre-established weighing intervals.

The floristic composition of the grassland vegetation was analyzed using the geobotanical method, applying the Braun-Blanquet scale, according to the methodology described by Păcurar and Rotar (2014). The grassland typology was classified based on the work of Țucra and colleagues (1987). The agronomic evaluation of the plots was carried out in accordance with the standard procedures used in pedo-agronomic studies on grassland ecosystems.

In 2022, a genetic herd consisting of 10 heifers and one bull of the Highland breed was imported from Germany with the aim of forming the nucleus of an extensive cattle breeding system on the Cojocna Farm. The imported animals and their offspring were registered in the National Herd Book and integrated into the official breeding program, ensuring traceability and control of the genetic performance of the population. The entire imported herd, as well as its offspring, were registered in the official genealogical register and integrated into the national breeding program, thus ensuring genealogical records and monitoring of reproductive and productive performance.

RESULTS AND DISCUSSIONS

The calves have a low birth weight, which contributes to easy calving without the need for human intervention. The age at weighing varied depending on the individual, and the average daily gain (ADG) recorded was within the range specific to the breed, with values between 491 and 671 g/day. Cows are not milked in the rearing system applied, with all milk being used for natural suckling of calves, which promotes vigorous development and efficient weight gain.

The age at weighing varied considerably, so that the live weight and average daily gain (ADG) of the animals fell within the normal limits for the breed analyzed, with values ranging from 312 to 729 g/day. The cows are not milked, and the calves consume all their mother's milk, which contributes significantly to daily weight gain (Fig. 1, 2, and Table 1). Statistically significant differences between the weight gains of males and females were identified only at point P1, while at points P2, P3, and TDG (total daily gain), no significant differences between the sexes were recorded in terms of body weight (Table 1).

Fig. 1 Highland cattle
(Source: original)

Fig. 2 Highland cattle with calves
(Source: original)

Table 1

Official performance control of the Highland calves

Gender	Birth date	Birth weight (kg) P1	Age in days (210±45)	Weight (kg)	ADG-gr. (Average Daily Gain) P2	Age in days (365±45)	Weight (kg)	ADG-gr. (Average Daily Gain) P3	TDG-gr. (Total Daily Gain)
M	2022-12-12	26	283	117	322	343	241	627	474
M	2022-10-10	27	346	168	408	406	256	564	486
M	2022-12-20	28	275	189	586	335	272	729	657
M	2022-12-23	27	272	159	485	332	260	702	594
F	2022-12-10	22	285	115	326	345	240	632	479
F	2022-11-24	24	301	118	312	361	241	601	457
F	2022-12-29	23	266	120	365	326	245	681	523
F	2023-01-17	25	247	135	446	307	235	684	565
	P1				P2			P3	TDG
M	27±0.41b				450.11±56.21a			655.44±37.25a	552.77±43.96a
F	23.5±0.51a				362.28±29.87a			649.69±20.08a	505.99±23.96a
			M = Male				F= Female		

Average daily gains are given as mean of three replicates ± standard deviations. P1 - Birth weight (kg), P2 - Average Daily Gain (ADG-gr); P3 - Average Daily Gain (ADG-gr); and TDG - average total daily gain (ADG, g/day/ average). Effects were considered statistically significant when $p \leq 0.05$. Values in the same column followed by the same letter are not statistically different according to the Tukey HSD test. Beef cows are kept in an extensive system, on pasture, throughout the year. During the winter period (November-April), feeding consists exclusively of hay, in a minimum quantity of 12–15 kg per adult animal. Daily water consumption is approximately 50 - 100 liters per suckler cow, provided from available sources at will. Following the implementation of the grazing regime, two pasture plots with distinct floristic compositions were delimited:

PD1 – *Stipa capillata* - *Carex humilis* grassland (Fig. 3), identified in plots 11; the land has a slope of 45–50% and is oriented to the south and southwest. The vegetation cover of the phytocoenosis is approximately 70%, with no woody vegetation, and the degree of vegetation consumption is low, estimated at 10–15%.

PD2 – *Festuca rupicola* grassland; this species forms perennial herbaceous tufts, with heights varying between 1 and 20 cm.

The land has a slope of 10–15% and the same south-southwest orientation. Vegetation cover is approximately 75%, with no woody vegetation, and the degree of vegetation consumption is high, estimated at approximately 70%. In PD1 of block 11, the type of grasslands *Stipa capillata* - *Carex humilis* was identified, the study plot having a slope of 45-50% and is oriented south and southwest. The general vegetation coverage of the phytocenosis is 70%, without woody vegetation. The degree of vegetation consumption is low, approximately 10-15%. (Table 2). In PD2 of block 11, the type of *Festuca rupicola* grasslands was identified. The study plot has a slope with values between 10-15% and is oriented south and southwest. The general vegetation coverage of the phytocenosis is 75%, devoid of woody vegetation. The degree of vegetation consumption is high, approximately 70% (Table 3).

Fig. 3 The distribution of the grassland, grazed with Highland
(Source: The original map QGIS)

Table 2

Floristic composition of the type of grassland *Stipa capillata* - *Carex humilis*

Species	Vegetative cover %	Degree of vegetation consumption
Botriochloa ischaemum	5	
Bromus arvensis	0,5	
Festuca rupicola	2,5	
Festuca valensiaca	2,5	
Medicago falcata	5	
Carex humilis	12,5	5
Stipa capillata	17,5	3
Aropyron cristatum	3	
Agropyron intermedium	0,5	
Asperula cynanchica	2,5	
Centaurea micranthos	0,5	
Centaurium erythraea	0,5	
Eryngium campestre	0,5	
Euphorbia cyparissias	0,5	

Filipendula hexapetala	0,5	
Fragaria viridis	0,5	
Peucedanum tauricum	2,5	
Viola spp	0,5	
Plantago media	0,5	
Potentilla arenaria	0,5	
Salvia nemorosa	0,5	
Teucrimum chamaedrys	2,5	
Thymus glabrescens	5	
Veronica orchidea	2,5	

Table 3

Floristic composition of the type of grassland *Stipa capillata* - *Carex humilis*

Species	Vegetative cover %	Degree of vegetation consumption
Agropyron intermedium	2,5	
Bothriochloa ischaemum	2,5	
Bromus arvensis	0,5	
Festuca rupicola	12,5	7
Festuca valesiaca	2,5	3
Medicago falcata	0,5	
Trifolium repens	0,5	
Astragalus onobrychis	0,5	
Achillea millefolium	5	
Carduus acanthoides	5	
Centaurea micranthos	2,5	
Convolvulus arvensis	0,5	
Eryngium campestre	2,5	
Euphorbia cyparissias	5	
Fragaria viridis	5	
Inula britannica	0,5	
Peudedanum tauricum	0,5	
Veronica spicata	0,5	
Plantago lanceolata	2,5	
Plantago media	0,5	
Potentilla arenaria	0,5	
Salvia nemorosa	0,5	
Thymus glabrescens	2,5	
Xeranthemum annuum	2,5	
Artemisia austriaca	2,5	
Adonis vernalis	0,5	
Carthamus lanatus	2,5	

CONCLUSION

To maintain their genetic origin and be recognized as Highland cattle for meat production, imported cattle must be officially registered in the national herdbook. This measure is essential for maintaining genetic traceability and properly integrating these animals into selection and breeding programs. The Highland breed has adapted well to the soil and climatic conditions of the Cojocna area. However, these animals have been observed to show a marked preference for shaded areas. Therefore, pasture management should include maintaining or planting trees in grazing areas to ensure a suitable microclimate. The extensive free-grazing system is generally suitable for this rustic breed. In some areas, however, intensive pasture use has led to overgrazing. This has favored the establishment of the region's typical *Festuca rupicola* vegetation and nitrophilous species, indicating an imbalance in the floristic composition. The Highland breed efficiently utilizes pastures with average productivity and plays an important role in maintaining and improving the conservation status of the Natura 2000 protected habitat Suatu-Cojocna-Crairât. Through appropriate grazing, these animals contribute to maintaining biological diversity and preserving the traditional landscape. In Cojocna, under specific conditions, the Highland breed has achieved average weight gains within the breed's characteristic parameters. This confirms its adaptability and zootechnical potential in the area.

RECOMMENDATION

Research on the adaptability of the Highland breed in different farming systems and on various types of pastures should continue and expand, focusing on the impact on biodiversity and economic efficiency. Switching to an organized grazing system based on the division of grazing areas is also recommended. This management strategy enables more balanced use of feed resources, prevents overgrazing, and promotes the natural regeneration of grass.

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THE QUALITY INDICES OF FODDER FROM *Cichorium intybus* AND *Carthamus tinctorius*, GROWN UNDER THE CONDITIONS OF THE REPUBLIC OF MOLDOVA.

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Abstract. *We evaluated the quality indices of fodder produced from chicory (Cichorium intybus) and safflower (Carthamus tinctorius) grown in monoculture on the experimental plots of the "Alexandru Ciubotaru" National Botanical Garden (Institute), MSU, Chişinău, Republic of Moldova. The results revealed that the dry matter of whole plants of studied species contained: 9.22-11.50% CP, 8.68-10.84% minerals, 27.80-32.91% CF, 40.93-51.96% NFE, 5.02-15.80% soluble sugars, 6.61-9.04 % starch, 9.40-11.80 g/kg Ca, 3.00 g/kg P; the nutritive energy value was 9.10-9.83 MJ/kg ME and the net energy for lactation (NEl) – 5.04-5.63 MJ/kg. The prepared silages had the following characteristics: pH=4.14-4.19, 25.0-35.7 g/kg lactic acid, 2.7-5.12 g/kg acetic acid. The dry matter of the silages contained 8.42-9.22% CP, 9.76-8.425% minerals, 33.20-33.51% CF, 41.95-46.22% NFE, 2.09-4.09% soluble sugars, 7.19-10.00 % starch, 9.70-15.10 g/kg Ca, 2.50-2.80 g/kg P, with nutritive energy value 9.18-9.21 MJ/kg ME and net energy for lactation 5.09-5.14 MJ/kg. The green mass and the silage prepared from Cichorium intybus and Carthamus tinctorius contain a lot of nutrients are rich in essential nutrients, making them suitable alternatives for the traditional livestock fodders.*

***Keywords**: biochemical composition, forage value, green mass, hay, Cichorium intybus, Carthamus tinctorius, silage.*

INTRODUCTION

In the context of climate change, diversifying the range of forage crops used to provide livestock with a stable and balanced diet plays a crucial role in the restoration and sustainable development of agriculture, as well as in ensuring food safety and security.

The *Asteraceae* family, the largest group of flowering plants, comprises approximately 27,773 species. Several of these species play important roles as food, forage, industrial, medicinal, ornamental or energy crops.

As part of ongoing activities to conserve and sustainably utilize plant genetic resources, new taxa from the *Asteraceae* family have been identified and mobilized over the years. These taxa originate both from local flora and from other floristic regions, and possess a wide range of economic uses. Research has led to the identification of valuable plant forms suitable for the development of new varieties. Notably, studies have highlighted the biological characteristics and forage potential of species such as *Cynara* *carduncululus, Echinacea purpurea, Helianthus annuus, Helianthus mollis, Helianthus strumosus, Helianthus tuberosus, Inula helenium, Silphium perfoliatum, Silybum marianum* etc. (ȚÎȚEI et al., 2013; ȚÎȚEI & COȘMAN, 2016; ȚÎȚEI, 2020, 2024; COȘMAN et al., 2023 GUȚU et al., 2023). *Cichorium* L. is a small genus of the *Asteraceae* family, consists of six species, while the two cultivated *Cichorium intybus* and *Cichorium endivia* (BIRSA et al., 2023). Chicory, *Cichorium intybus* L. is native to Europe, temperate Asia, northern Africa, and has been naturalized in other regions. It is perennial herbaceous plant characterized by fusiform, twisted roots, up to 1-1.5 cm thick and up to 1.5 m long. It has an erect, branched stem with prominent grooves and is covered in rough hairs, reddish brown, wooded at base, containing latex, 30–120 cm tall. The basal leaves arranged in a rosette, oblanceolate, petiolate 7–30 cm long, 1–12 cm wide, apex acute, margins toothed to pinnatisect with toothed lobes, pubescent to glabrous; the lower stem leaves similar to the basal ones; the upper leaves alternate, sessile, smaller, cordate at the base, covered with hairs. The ligulate flowers are blue, found in flower head inflorescences, which are typically solitary or grouped by 2-3, terminal or sometimes axillary. The fruit is an achene, 2-3 mm long, with a very short pappus. It blooms from July to September. *Cichorium intybus* has good tolerance to drought and frost and low tolerance against waterlogging and salt. It requires deep, well-drained fertile soil with good nitrogen content. *Cichorium intybus* has been researched and cultivated in several research centers as a food, fodder and medicinal plant (MORARU et al., 2012; CIOCÂRLAN, 2014; DRAGOMIR et al., 2018; BIRSA et al., 2023), also it is a good source of protein feed and nectar for bees, honey productivity 166.59 - 301.34 kg/ha. (ADAMCHUK et al. 2017).

The genus *Carthamus* L., *Asteraceae* family comprises 48 accepted species names, of which only *Carthamus tinctorius* L., is cultivated and the rest are wild and weedy in habit. The areas of origin of safflower, *Carthamus tinctorius,* are Africa, the Middle-East and Asia. It is an annual herbaceous plant with a strong erect, glabrous, branched stem, 30-150 cm in height. The leaves are ovate- obovate, alternate, the lower ones are sessile and acuminate. The inflorescence is a dense capitulum of flowers, surrounded by an involucre of green ovoid bracts. The florets are small, tubular, sessile, composed on type 5. The fruit is a smooth, shiny and angular achene. This species is a drought, heat, cold and salinity tolerant crop, it is considered as a climate-smart crop, adaptable to more variable environmental conditions and soils as compared with other species in the Asteraceae family. Safflower is a multipurpose oil seed crop that can be used for the production of cooking oil, as a food crop, cut flowers, fodder crop for both fresh and preserved animal feed, industrial crop for dye production and as a medicinal crop (DOBRIN & MARIN, 2015; HEUZÉ & TRAN, 2015; IVANOVA, 2016; KOCAMAN et al., 2016; EMONGORN & OAGILE, 2017; PEIRETTI, 2017; SEENO 2023; LÓPEZ-JARA et al. 2025).

The main objective of this study was to evaluate the quality indices of fodder from two *Asteraceae* species – *Cichorium intybus* and *Carthamus tinctorius* – cultivated under the conditions of the Republic of Moldova.

MATERIALS AND METHODS

The study was conducted using a local ecotype of chicory (*Cichorium intybus*) and an introduced spineless ecotype of safflower (*Carthamus tinctorius*), both cultivated in monoculture on an experimental plot at the "Alexandru Ciubotaru" National Botanical Garden (Institute) of Moldova State University (MSU), located in Chişinău (latitude 46°58′25.7″N, longitude 28°52′57.8″E). Traditional crops, specifically the corn hybrid 'GW9003' (*Zea mays*) and the sunflower hybrid 'HS9729' (*Helianthus annuus*), served as controls. Plant samples of *Cichorium intybus*, *Carthamus tinctorius*, and *Helianthus annuus* were collected at the flowering stage, while *Zea mays* was harvested at the wax stage of grain development. The harvested biomass was chopped into 1.5-2.0 cm pieces using a laboratory forage chopper. The dry matter content was determined by drying samples to a constant weight at 105°C. Silage was prepared from the chopped green mass by compressing it into well-sealed glass containers, which were stored at ambient temperatures (18–20°C). After 45 days, the containers were opened, and the sensorial and fermentation characteristics of the preserved forage were assessed according to the standard SM 108* accepted in the Republic of Moldova.

Both green mass and fermented fodder samples were dehydrated in a forced-ventilation oven at 60°C. Once dried, the biological material was finely ground using a laboratory ball mill. Fodder quality was evaluated based on several parameters: crude protein (CP), crude fiber (CF), crude fat (EE), nitrogen-free extract (NFE), soluble sugars (SS), starch, ash, calcium (Ca), phosphorus (P), silage pH, and concentrations of organic acids (lactic (LA), acetic (AA), and butyric (BA) in both free and fixed forms.

Energy values, namely: gross energy (GE), metabolizable energy (ME), and net energy for lactation (NEl), were calculated following standard methodological procedures:

GE=23.9xCP+39.8xEE+20.1xCF+17.5xNFE;

ME=14.07+0.0206xEE-0.0147xCF--0.0114xCP+4.5%;

NEl=9.10+0.0098xEE-0.0109xCF-0.0073xCP.

RESULTS AND DISCUSSION

At harvest, *Cichorium intybus* plants averaged 120-126 cm in height, while *Carthamus tinctorius* plants measured 97-105 cm. The fresh mass productivity of the introduced spineless safflower ecotype reached 3.74 kg/m², corresponding to 1.10 kg/m² of dry matter. In comparison, the local ecotype of chicory yielded 5.89 kg/m² of fresh mass, or 1.31 kg/m² of dry matter.

Several studies have reported varying productivity levels for these species. CAZZATO et al. (2011) found that safflower dry matter productivity ranged from 4.5 to 11.6 t/ha. ELGERSMA et al. (2014) reported a herbage productivity of 9,960 kg/ha for chicory. UMAMI et al. (2019) observed that *Cichorium intybus* could achieve up to 28.12 t/ha/year of organic matter. NECIU et al. (2017) indicated that under different natural and technological conditions, pure chicory cultures yielded between 30–60 t/ha of green mass or 7-15 t/ha of dry matter. DRAGOMIR et al. (2018) noted a dry matter yield of 6.59 t/ha for non-fertilized chicory, increasing to 8.54 t/ha with fertilization. OCHOA-ESPINOZA et al. (2022b) reported that safflower dry matter productivity varied from 4,461 to 10,816 kg/ha. JABARI et al. (2023) recorded the highest forage yield among the studied safflower cultivars at 52,103 kg/ha of fresh mass or 11,900 kg/ha of dry matter. Similarly, KARGAR et al. (2024) found that the ‘Golmehr’ cultivar of safflower, harvested at the branching stage, achieved yields of 42,229 kg/ha fresh mass and 11,266 kg/ha dry matter.

The nutrient composition and energy value of the harvested fresh fodder from *Cichorium intybus* and *Carthamus tinctorius* are presented in Table 1. Comparative analysis of the whole-plant nutrient content showed that the fresh forage of both species had a higher crude protein level than that of traditional forage crops such as corn (*Zea mays*) and sunflower (*Helianthus annuus*). Chicory forage was notable for its significantly higher crude fat content, while safflower fodder had a lower crude fat concentration compared to corn and sunflower. The crude fiber content in safflower fodder was within the optimal range, while in chicory forage, it did not differ significantly from that in sunflower forage. Safflower fodder had higher levels of nitrogen-free extract and starch than sunflower, but these values were lower than those found in corn forage. Chicory forage contained less soluble sugar but more starch compared to both sunflower and safflower. The ash content in chicory fodder was similar to that of sunflower but higher than in safflower and corn. For both *Carthamus tinctorius* and *Cichorium intybus*, the calcium and phosphorus content exceeded that found in corn forage. However, as compared to sunflower, both fodders had lower calcium content but higher phosphorus levels. The gross energy concentrations in safflower and sunflower fresh fodder were similar, but both were lower than those in chicory and corn forage. Safflower forage had higher metabolizable energy (ME) and net energy for lactation (NEl) than chicory and sunflower, though still lower than in corn. Various studies in the specialized literature report differing results regarding the nutrient content of harvested green biomass from *Carthamus tinctorius* (safflower) and *Cichorium intybus* (chicory) plants. According to LESHEM et al. (2000), safflower herbage contained 10.0-14.6% crude protein (CP) and 489–656 g/kg dry matter digestibility (DMD). STANFORD et al. (2001) reported that *Carthamus tinctorius* harvested at full bloom had a forage composition of 9.7% CP, 1.6% ether extract (EE), 32.1% neutral detergent fiber (NDF), 23.1% acid detergent fiber (ADF), and 636 g/kg effective rumen degradability of dry matter. BROWN & MOOT (2004) observed that the palatable fraction of *Cichorium intybus* forage contained 18% CP and 13.3 MJ/kg metabolizable energy (ME), while the unpalatable fraction had 8% CP and 9.4 MJ/kg ME. WEINBERG et al. (2007) reported safflower herbage nutrient values of 12.2-22.1 g/kg nitrogen, 287-364 g/kg ADF, 410-478 g/kg NDF, 66-104 g/kg water-soluble carbohydrates (WSC), and 521-693 g/kg DMD.

Table 1.

The nutrient composition and energy value of fresh forage biomass from *Cichorium intybus* and *Carthamus tinctorius* as compared with traditional crops

Indices	*Cichorium intybus*	*Carthamus tinctorius*	*Helianthus annuus*	*Zea mays*
Crude protein, % dry matter	11.50	9.22	8.15	6.93
Crude fats, % dry matter	3.82	2.34	3.00	2.61
Crude cellulose, % dry matter	32.91	27.80	33.11	17.24
Nitrogen free extract, % dry matter	40.93	51.96	44.96	69.73
Soluble sugars, % dry matter	5.02	15.80	12.30	6.81
Starch, % dry matter	9.04	6.61	3.99	23.05
Ash, % dry matter	10.84	8.68	10.78	3.48
Calcium, g/kg dry matter	11.80	9.40	12.40	2.30
Phosphorus, g/kg dry matter	3.00	3.00	2.90	2.40
Gross energy, MJ/kg dry matter	18.04	17.82	17.67	18.37
Metabolizable energy, MJ/kg dry matter	9.10	9.83	8.89	11.29
Net energy for lactation, MJ/kg dry matter	5.04	5.63	4.98	6.93

Table 2.

The fermentation profile, chemical composition and energy value of silage from *Cichorium intybus* and *Carthamus tinctorius* as compared with traditional crops

Indices	*Cichorium intybus*	*Carthamus tinctorius*	*Helianthus annuus*	*Zea mays*
pH index	4.19	4.14	4.39	3.73
Organic acids, g/kg dry matter	35.7	25.0	48.9	45.0
Free acetic acid, g/kg dry matter	1.0	0.6	4.2	3.6
Free butyric acid, g/kg dry matter	0	0	0.1	0
Free lactic acid, g/kg dry matter	2.3	6.0	10.8	16.7
Fixed acetic acid, g/kg dry matter	4.1	2.1	6.5	3.8
Fixed butyric acid, g/kg dry matter	0.1	0.1	0.8	0.2

Fixed lactic acid, g/kg dry matter	28.2	16.2	26.5	20.7
Total acetic acid, g/kg dry matter	5.1	2.7	10.7	7.4
Total butyric acid, g/kg dry matter	0.1	0.1	0.9	0.2
Total lactic acid, g/kg dry matter	30.5	22.2	37.3	37.4
Acetic acid, % of organic acids	14.29	10.80	21.88	16.44
Butyric acid, % of organic acids	0.30	0.45	1.84	0.44
Lactic acid, % of organic acids	85.41	88.75	76.28	83.12
Crude protein, % dry matter	10.92	8.42	7.67	6.83
Crude fats, % dry matter	4.17	3.06	2.54	3.50
Crude cellulose, % dry matter	33.20	33.51	36.42	16.47
Nitrogen free extract, % dry matter	41.95	46.22	42.64	69.69
Soluble sugars, % dry matter	2.09	4.09	0.43	0.79
Starch, % dry matter	10.00	7.19	0.66	24.82
Ash, % dry matter	9.76	8.80	10.73	3.52
Calcium, g/kg dry matter	15.10	9.70	10.60	2.30
Phosphorus, g/kg dry matter	2.50	2.80	2.10	2.50
Gross energy, MJ/kg dry matter	18.37	18.05	17.63	18.53
Metabolizable energy, MJ/kg dry matter	9.18	9.21	8.37	11.59
Net energy for lactation, MJ/kg dry matter	5.09	5.14	4.82	7.14

ARSLAN et al. (2008) found that pure safflower herbage contained 7.3% CP, 27.6% crude fiber (CF), 35.8% ADF, 44.6% NDF, 17.2 g/kg calcium (Ca), and 3.4 g/kg phosphorus (P). In contrast, mixtures of field pea and safflower showed improved nutrient profiles: 12.2-16.4% CP, 22.9-25.7% CF, 30.8-33.4% ADF, 39.1-42.4% NDF, 12.6-15.4 g/kg Ca, and 3.2-3.3 g/kg P. BAR-TAL et al. (2008) indicated that the forage value of *Carthamus tinctorius* varied depending on nitrogen fertilization and irrigation levels, with results ranging between the following indices 13.1-20.5 g/kg nitrogen, 4.8-8.8% ash, 30.9-43.9% ADF,44.8-56.8% NDF, 4.70-8.98% WSC, and 521-693 g/kg *in vitro* dry matter digestibility (IVDMD).

CHAPMAN et al. (2008) reported that during its establishment year, chicory produced 1,350-1,924 kg/ha of dry matter with a CP content of 14.4-16.6% and 59.2% NDS. MASSOUD et al. (2009) found that chicory leaves contained 14.70% CP, 10.91% ash, 16.78% CF, 70.71% total carbohydrates, 7.80% total soluble sugars, and 0.29% Ca. PEIRETTI (2009) analyzed safflower forage harvested at five morphological stages, finding nutrient and energy concentrations ranging from 83–157 g/kg DM, 12.4–27.2% CP, 2.2–2.9% CF, 17.2–41.5% ADF, 31.3–49.1% NDF, 10.7–17.1% ash, and 16.2–17.8 MJ/kg gross energy. HAYES et al. (2010) noted that whole chicory plants harvested in early summer contained 13.1% CP, 43.2% NDF, 24.8% ADF, 12.6% ash, 64.24% DMD, and 9.07 MJ/kg ME. SUN et al. (2011) reported that chicory forage had 89 g/kg DM, 11.7% CP, 28.1% NDF, 21.3% ADF, 8.0%

ADL, and 14.4% ash. Finally, KHAN et al. (2013) found that *Cichorium intybus* contained 13.51% CP, 49.50% NDF, 38.73% ADF, 2.86% ash, and 0.62% Ca. For comparison, *Medicago polymorpha* showed higher values: 21.54% CP, 53.64% NDF, 42.83% ADF, 11.28% ash, and 1.02% Ca. DANIELI et al. (2011) reported that the nutritional characteristics of spineless safflower grown under Mediterranean climatic conditions were as follows: 11-17% CP, 39.8-43.9% CF, 33.1–35.4% aADF, 42.9-45.9% aNDF, 7.4-11.7% ADL, and 12.4-13.2% ash. ASGHARZADEH et al. (2013) found that *Carthamus tinctorius* herbage, depending on the amount and type of applied fertilizers, contained 343-380 g/kg dry matter, 9.5-13.8% CP, 37.2-42.1% NDF, 32.7-35.7% ADF, 5.2-5.4% WSC, 6.0-11.7% ash, 10-12 g/kg Ca, 2.9-3.9 g/kg P, 57.1-68.2% OMD, and 8.5-10.0 MJ/kg ME. DANIELI et al. (2014) confirmed similar findings for spineless safflower under Mediterranean conditions, reporting values of: 11-17% CP, 39.8–43.9% CF, 33.1-35.4% aADF, 42.9-45.9% aNDF, 7.4-11.7% ADL, and 12.4-13.2% ash. PILUZZA et al. (2014) reported that the chemical composition of chicory leaves included 162-200 g/kg CP, 290.6-336.8 g/kg ADF, 366-406.5 g/kg NDF, 570.4-638.2 g/kg total digestible nutrients, 621.6-662.6 g/kg digestible dry matter, a relative feed value of 143.7-170.6, and 1.401-1.539 Mcal/kg NEl.RETA SANCHEZ et al. (2014) found that *Carthamus tinctorius* herbage, depending on row spacing, contained 17.1-19.5% CP, 43.7-48.1% NDF, 33.3-35.7% ADF, and 1.37-1.43 Mcal/kg NEl. HEUZÉ & TRAN (2015) reported that the biochemical composition and nutritive value of safflower dry matter was: 15.0% CP, 11.3% ash, 14.0 g/kg Ca, 3.4 g/kg P, 65.1% digestible organic matter, 17.5 MJ/kg GE, and 9.3 MJ/kg ME. Muir et al. (2015) found that forage from a second-year chicory crop contained 271 g/kg dry matter and the following composition: 13.57% ash, 6.1% CP, 48.8% NDF, 32.4% ADF, with an estimated digestible energy of 7.6 MJ/kg. KIRILOV et al. (2016) reported that *Cichorium intybus* contained 7.56% ash, 7.16% CP, 35.26% CF, and 46.68% NFE, whereas *Medicago sativa* had 8.14% ash, 16.92% CP, 1.41% EE, 27.53% CF, and 46.00% NFE. ÇAĞRI & KARA (2018) reported that the forage value of safflower green mass was: 8.10% CP, 6.51% DP, 39.05% aNDF, 31.99% aADF, 4.75% ADL, and 2040.83 kcal/kg ME. DRAGOMIR et al. (2018) found that the crude protein content in chicory forage was 22.62% in the non-fertilized variant and 25.06% in the nitrogen-fertilized variant. NIDERKORN et al. (2019) reported that chicory forage contained 103 g/kg dry matter, 14.2% CP, 35.3% NDF, 20.8% ADF, and 6.3% ADL. SUN et al. (2020) noted that chicory forage had 11.4% CP, 23.9% NDF, 18.8% ADF, 5.1% hemicellulose (HC), 10.6% cellulose (Cel), and 19.6% ash. AMALYADI et al.

(2022) stated that chicory forage harvested at 45 days had the following nutritional values depending on treatment: 17.23-19.41% CP, 12.12-13.43% CF, 76.11-77.53% DDM, and 70.36-73.69% OMD. ÇALIŞKAN & YÜKSEL (2022) found that the nutrient composition of safflower forage dry matter was: 8.36–12.29% CP, 31.30–47.92% NDF, and 27.61–38.59% ADF. OCHOA-ESPINOZA et al. (2022a) found that the forage value of spiny safflower cultivars was as follows: 22.6-23.3% CP, 46.7-47.7% NDF, 38.1-38.9% ADF, 64-65% IVDMD, and 5.36-5.48 MJ/kg NEl. In contrast, the spineless safflower cultivar 'Selkino' contained 24.7% CP, 47.5% NDF, 39% ADF, 67.4% IVDMD, and 5.73 MJ/kg NEl. LÓPEZ-JARA et al. (2022) reported that the forage value of *Carthamus tinctorius* was 16.2-17.9% CP, 40.2-46.3% NDF, 31.8-38.0% ADF, and 5.4-6.1 MJ/kg NEl, while *Brassica napus* forage had, respectively, 17.1-19.9% CP, 36.8-45.7% NDF, 30.4-35.9% ADF, and 5.7-6.3 MJ/kg NEl. OCHOA-ESPINOZA et al. (2022b) revealed that the forage from *Carthamus tinctorius* cultivars was characterized by 17.79-24.35% CP, 49.46-50.91% NDF, 39.82-43.34% ADF, 53.58-58.58% IVDMD, and 4.37-4.87 MJ/kg NEl. STOYCHEVA & GEORGIEVA (2022) reported that chicory green mass contained 212.4 g/kg dry matter, with 8.16% ash, 9.48% CP, 27.84% CF, and 51.27% NFE. VERMA et al. (2022) found that the chemical composition of first-cut chicory plants included 12.2-18.1% CP, 34.6-46.4% NDF, and 21.2-28.1% ADF. At the second cut, chicory fodder had 13.7-22.0% CP, 30.1-44.9% NDF, and 23.2-30.1% ADF. BASBAG & SAYAR (2023) reported that the fodder harvested at the blooming stage from *Cichorium intybus* contained 20.55% CP, 30.19% NDF, 21.78% ADF, 1.46% Ca, 0.30% P, 71.74% DMD, 11.43 MJ/kg ME, and a relative feed value of 221.7. In comparison, the fodder from *Sylibum marianum* had 18.59% CP, 30.38% NDF, 24.61% ADF, 1.54% Ca, 0.34% P, 69.73% DMD, 11.01 MJ/kg ME, and RFV = 219.3. MIKULOVÁ et al. (2023) reported that the nutrient composition of dry matter from chicory plants included 19.8% CP, 38.4% NDF, 28.2% ADF, and 7.4% ash. SEENO (2023) found that the nutritive value of harvested chicory monoculture in spring was: 12.9-16.3% CP, 32.3% aNDF, 23.7-24.1% ADF, and 11.8-12.1% ash, but in summer, the values were 10.4-11.3% CP, 35.4-37.0% aNDF, 26.7-27.9% ADF, and 12.4% ash, respectively. JABARI et al. (2023) observed that the crude protein content in safflower plants harvested at the branching stage was 14.57%, while the maximum CP content, 19.22%, was observed at the flowering stage. KARGAR et al. (2024) reported that safflower forage harvested during the stem elongation stage contained 11.6-13.9% CP, 8.5-15.7% WSC, 28.6-32.0% CF, 9.5-10.2% ash, 61.8-66.9% DDM, 52.5-59.8% TDN, and an RFV of 85.5-107.6, in contrast, the forage harvested at the branching stage had 18.5-19.8% CP, 8.4-13.2% WSC, 31.5-35.5% CF, 10.1-10.6% ash, 65.9-71.5% DDM, 56.0-64.2% TDN, and an RFV of 86.1-129.0. Silage making is a widely used and effective method of forage preservation and serves as a critical strategy for ensuring a consistent, high-quality fodder supply throughout the year. During sensory evaluation, the ensiled mass of *Carthamus tinctorius* and *Cichorium intybus* was found to contain dark green leaves and yellow stems. The silage emitted a specific but mild and pleasant smell. Its texture remained consistent as compared to the original green mass, showing no signs of mold or mucus formation. The results of the silage quality indices for safflower and chicory are presented in Table 2. Safflower silage had a dry matter content of 282.5 g/kg, while chicory silage contained 264.4 g/kg. The pH value, a key indicator of fermentation quality, ranged from 4.14 to 4.19 for both silages. These values were higher than those typically observed in corn silage but within the optimal range when compared with sunflower silage. Total organic acid concentrations ranged from 25.0 g/kg in safflower silage to 35.7 g/kg in chicory silage – both lower than those found in corn and sunflower silages. Most organic acids were present in bound form. Acetic acid concentrations in both safflower and chicory silages were lower than in corn and sunflower silages. Butyric acid was detected only in trace amounts (0.1 g/kg), significantly lower than in sunflower silage. Lactic acid constituted 85.4–88.7% of the total organic acids in both silages, indicating a favorable fermentation process and good silage quality. During ensiling, the biochemical composition underwent noticeable changes. The levels of crude protein, soluble sugars, and phosphorus decreased, while crude fat and calcium concentrations increased. In safflower silage, crude fiber content rose significantly, while nitrogen-free extract declined. The metabolizable energy (ME) and net energy for lactation (NEl) in safflower silage were lower than in the original fresh mass. In contrast, chicory silage showed no significant difference in energy values as compared to its initial green mass. It is worth noting that chicory and safflower silages were characterized by higher contents of crude protein, crude fat, soluble sugars, starch, phosphorus, metabolizable energy and net energy for lactation compared to sunflower silage. When compared with corn silage, both chicory and safflower silages had higher concentrations of crude protein, crude fiber, soluble sugars, ash, calcium, and phosphorus. However, corn silage had the highest overall energy values among the four silage types. Several literature sources describe the quality indices of silage prepared from *Carthamus tinctorius* and *Cichorium intybus* plants. For example, WEINBERG et al. (2002) found that the silage made from wilted *Carthamus tinctorius* plants contained 290-411 g/kg dry matter, with a pH of 4.46, 19-20 g/kg lactic acid, 4-6 g/kg acetic acid, 85-89 g/kg crude protein, 86-92 g/kg ash, and 15-28 g/kg water-soluble carbohydrates. Inoculated safflower silages had improved fermentation characteristics: pH 3.9-4.1, 42–47 g/kg lactic acid, 6-8 g/kg acetic acid, and 12-20 g/kg WSC. CORLETO et al. (2005) reported that safflower silage produced from plants harvested at 25% flowering stage had a pH of 4.46, 18.7 g/kg lactic acid, 4.7 g/kg acetic acid, and 376 g/kg dry matter. The nutritional profile included 8.0% CP, 49.3% NDF, 37.3% ADF, 5.9% ADL, 5.27% WSC, and 6.9% ash. In contrast, the silage made from plants inoculated with *Lactobacillus plantarum* showed improved values: pH 4.15, 29.2 g/kg lactic acid, 5.7 g/kg acetic acid, 399 g/kg dry matter, 8.6% CP, 51.2% NDF, 37.6% ADF, 6.1% ADL, 4.97% WSC, and 9.8% ash. WEINBERG et al. (2007) noted that *Carthamus tinctorius* silage produced under different irrigation and nitrogen fertilization regimes had a pH range of 4.0-4.8, and contained 34-127 g/kg lactic acid, and 4-15 g/kg acetic acid. ASGHARZADEH et al. (2013) found that safflower silages had pH values of 4.7-4.9, and contained 90-130 g/kg lactic acid, 290-433 g/kg dry matter, 12.3-14.8% CP, 45.3-49.0% NDF, 37.2-42.1% ADF, 1.9-2.8% WSC, 9.0-12.3% ash, 10-13 g/kg Ca, 3.0-4.2 g/kg P, 56.2-65.4% OMD, and 8.2–9.6 MJ/kg ME. HEUZÉ & TRAN (2015) reported that safflower silage contained 12.6% CP, 31.4% CF, 8.9% ash, 70.2% DOM, 17.5 MJ/kg gross energy, and 10.6 MJ/kg ME. PEÑA-ESPINOZA et al. (2016) indicated that chicory silage had 357 g/kg dry matter, 20.7% ash, 9.3% CP, 32.6% NDF, 62% OMD, and 6.5 MJ/kg ME. SÁNCHEZ-DUARTE et al. (2018) reported that *Carthamus tinctorius* silage contained 372.6 g/kg dry matter, 17.7% CP, 45.16% NDF, 491.5 g/kg TDN, and 1.11 Mcal/kg NEl. STOYCHEVA et al. (2019) observed that *Cichorium intybus* silage had 195 g/kg dry matter and a pH of 4.69, while chicory haylage contained 521 g/kg dry matter and a pH of 4.25. CAN et al. (2020) found that chicory silage was characterized by a pH of 4.19, 17.8 g/kg lactic acid, 1.43 g/kg acetic acid, and 0.16 g/kg butyric acid. The silage had 267.5 g/kg dry matter, 11.21% ash, 1.13% Ca, 0.37% P, 15.35% CP, 33.11% NDF, and 26.30% ADF. STOYCHEVA &GEORGIEVA (2022) reported that chicory silage contained 212.4 g/kg dry matter, with a pH of 4.04, 8.73% ash, 9.15% CP, 31.53% CF, and 46.72% NFE. FORD et al. (2024) stated that chicory silage had 8.7% CP, 51.7% NDF, 46.0% ADF, 1.06 Mcal/kg NEl, and a relative feed value of 96. LÓPEZ-JARA et al. (2025) found that the silage prepared from *Carthamus tinctorius* had a pH of 4.97, 448.1 g/kg dry matter, 17.88% CP, 37.10% NDF, 28.45% ADF, 10.11% ADL, 19.12% ash, 657.0 g/kg TDN, and 1.57 Mcal/kg NEl. In comparison, *Avena sativa* silage had a pH of

4.75, 388.0 g/kg dry matter, 13.76% CP, 52.02% NDF, 32.20% ADF, 4.26% ADL, 12.84% ash, 604.2 g/kg TDN, and 1.38 Mcal/kg NE.

CONCLUSIONS

The green mass forage and the silage prepared from *Cichorium intybus* and *Carthamus tinctorius* are rich in crude protein and other essential nutrients, making them suitable alternatives for the traditional livestock fodders.

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THE YIELD AND QUALITY OF GREEN MASS OF *GLYCINE MAX* GROWN IN THE CENTRAL ZONE OF THE REPUBLIC OF MOLDOVA

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Abstract. *Soybean, Glycine max, is considered one of the most important agricultural plants for human and animal nutrition. We investigated the yield and quality indices of the green from local cultivar 'Aura' of soybean, Glycine max, cultivated under non-irrigated conditions, in the experimental plot of the Central zone, Republic of Moldova. The results revealed that the soybean green mass yield was 3.83 kg/m^2 or 1.07 kg/m^2 dry matter. The biochemical composition and forage value of the dry matter were as follows: 17.5% CP, 8.6% ash, 31.0% CF, 33.2% ADF, 52.0% NDF, 6.1 % ADL, 9.1% TSS, 27.1% Cel, 18.8% HC, 630 g/kg DDM, RFV= 113, 12.41 MJ/kg DE, 10.19 MJ/kg ME and 6.21 MJ/kg NEl. These findings suggest that the local cultivar 'Aura' of soybean (Glycine max) may be cultivated as forage crops and the harvested biomass may be used as a part of diverse livestock diets.*

***Keywords**: biochemical composition, Glycine max, forage value, green mass, local cultivar 'Aura', yield*

For the sustainable development of agriculture and the cost-effective production of meat, milk, and other animal-derived raw materials for various industries, farmers require an affordable and readily available source of forage that is rich in protein and essential nutrients to support the health and productivity of farm animals (COŞMAN et al., 2023). *Fabaceae* plants play a major role in developing sustainable agriculture, due to their symbiotic relationship with nitrogen fixing bacteria, which help improving the physical properties of soil and fertility, contribute to preventing erosion and plant root diseases, and have a positive influence on the yield and quality of the plants cultivated after them on the same land. *Fabaceae* plants are an important source of proteins – a key element of human and animal nutrition. The genus *Glycine* Willd. is one of the most important genera in *Fabaceae* family. It is divided into two subgenera: *Glycine* Willd. – with 25-30 wild perennial species and *Soja* (Moench) F.J. Herm – with 2 annual species, *Glycine max* (L.) Merr.) and *Glycine soja* Sieb. and Zucc. Soybean (*Glycine max*, syn. *Glycine hispida*, *Glycine angustifolia*, *Soja japonica*), a species native to East Asia, was first domesticated in ancient China around 1100 B.C. and was introduced to Europe by the 1700s. Soybean is considered one of the most important agricultural crops for human and animal nutritions. Its seed is high in protein (35-42%), oil (18-23%) and other nutrients that are beneficial for human and animal health. Soybean is valued not only as a food source but also as a raw material for various industrial products, bioenergy, and forage. It serves as a reliable source of high-quality forage during late summer and autumn, particularly when other forages such as brassicas, perennial grasses, and legumes have already been harvested or are unavailable. Harvested soybean plants can be utilized as fresh biomass, hay, silage, or as a protein-rich supplement to other forages with deficient protein content (BLOUNT et al., 2013; HEUZÉ et al., 2016; BAŞARAN et al., 2017; TABACCO et al., 2017; ZANINE et al., 2020; IQBAL et al., 2021; HONG, 2022; THOMPSON et al., 2023; SUN et al., 2024; YÜCESOY & GARIPOĞLU, 2025).

In Romania, Bulgaria, and the Republic of Moldova, soybean breeding and cultivation have a history spanning over 100 years. Today, all three countries are following this heritage through breeding and registering new soybean varieties well adapted to local cropping conditions (DIMA 2015). The soil and climate conditions in the Republic of Moldova, particularly in the central and northern regions, are favorable for soybean cultivation. According to data provided by the National Bureau of Statistics, between 2000 and 2024, the annual area of land sown with soybeans in Moldova ranged from 20,000 to 63,000 hectares, representing 1.5% to 4.1% of the total area cultivated with herbaceous crops. Recently, there has been a noticeable increase in farmer interest in expanding soybean cultivation. The Catalogue of Plant Varieties of the Republic of Moldova currently includes 33 registered soybean cultivars, of which 14 local cultivars are nongenetically modified organisms. The goal of this research was to evaluate the yield and quality of green mass from soybean cultivar *Glycine max* 'Aura' grown under the conditions of the Central Zone of the Republic of Moldova.

MATERIALS AND METHODS

The local cultivar 'Aura' of soybean, *Glycine max*, created at the "Selectia" Research Institute of Field Crops Bălți and cultivated in the non-irrigated experimental plot of the "Alexandru Ciubotaru" National Botanical Garden (Institute), Central zone, Republic of Moldova, served as research subjects and the traditional forage crops: alfalfa (*Medicago sativa*) and corn (*Zea mays*) were used as control variants. The experiment was conducted using a randomized complete block design with four replications. Each experimental plot measured 50 m². Soybean and corn were sown on early May. Soybean was sown at a depth of 4.0 cm, with rows spaced 45 cm apart, while corn was sown with a row spacing of 70 cm. Green biomass was harvested manually. Soybean samples were collected at the early pod stage, corn at the kernel milk stage, and alfalfa at the third cut. The leaf-to-stem ratio was determined by separating the leaves from the stems, weighing them individually, and calculating the ratio of leaf to stem mass. The harvested plants were chopped into 1.5-2.0 cm pieces using a laboratory forage chopper. The dry matter content was determined by drying the samples at 105°C until a constant weight was achieved. For biochemical analysis, the plant samples were dried in a forced air oven at 60°C, milled in a beater mill equipped with a sieve with diameter of openings of 1 mm and some assessments of the main biochemical parameters: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS) were done by near infrared spectroscopy (NIRS) technique PERTEN DA 7200. The concentration of hemicellulose (HC), cellulose (Cel), digestible dry matter (DDM), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures.

RESULTS AND DISCUSSION

Based on the analysis of biomorphological characteristics and productivity, it was observed that soybean plants of the local cultivar 'Aura' reached 107-113 cm in height at the early pod stage, producing a green biomass yield of 3.83 kg/m², with a dry matter content of 28.0% and 61.7% consisting of leaves and pods. Different results regarding the green mass productivity of soybean plant, depending on cultivars and management practices, are given in the specialized literature. SHEAFFER et al. (2001) reported that dry matter yield of forage soybeans was 9.5-10.3t/ha. KOIVISTO et al. (2003) revealed that forage soybeans cultivars are able to produce up to 12 t/ha dry matter in southern England. AÇIKGÖZ et al. (2013) found that dry matter yield of forage soybean varied from 8.25 to 15.80 t/ha. MIHAILOVIC et al. (2013) mentioned that highest soybeans cultivar yield achieved 82.4 t/ ha green forage and 18.4 t /ha of dry matter. LEE et al. (2014) found that the average fresh forage yield of cultivated soybeans was 4.4-16.3 t/ha or 0.9-4.9 t/ha dry matters, while of wild soybean were 6.1 - 9.9 t/ ha fresh forage and 1.3-2.9 t/ ha dry matters, respectively. SERBESTER et al. (2015) mentioned that forage productivity of monocrop soybean was 29.9-32.5 t/ha green forage and 5.9-7.8 t/ha dry matter. SÜRMEN & KARA (2017) found that the herbage yield in pure culture of soybean was 15.2-25.2 t/ha green mass or 5.9-6.7 t/ha hay, but in buckwheat-soybean mixture 14.3-31.0 t/ha green or 4.8-11.09 t/ha hay. THU HONG et al.

(2021) remarked that soybean foliage yield was 38.9 t/ha with 23.9% dry matter content. HOMAN et al. (2021) showed that the forage soybean in pure culture achieved 134.8 cm plant height, 32.9 t/ha biomass yield and 9.7t/ha dry matter. IQBAL et al. (2021) reported that soybean forage productivity varied from 21.0 to 28.8 t/ha herbage yield and 5.1 to 7.3 t/ha dry matter. MOSSIE et al. (2021) revealed that soybean herbage dry matter productivity varied from 6.9 to 9.7 t/ha. STERNA et al. (2023) remarked that forage productivity of studied soybean cultivars harvested in different development stages was 13.5-34.7 t/ha green forage or 3.9-11.2 t/ha dry matter. THOMPSON et al. (2023) reported that dry matter yield of studied soybean cultivars was 1294-1744 kg/ha. The biochemical composition, nutritive and energy value of the fresh mass from soybean plants is presented in Table 1. A comparative analysis of the biochemical composition revealed that soybean fresh forage had higher crude protein content (175 g/kg) as compared to the third cut of alfalfa fresh forage (141 g/kg) and corn fresh forage (84 g/kg). The concentrations of crude fiber, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) in soybean forage were lower than those in alfalfa but higher than those in corn forage. The mineral content in soybean forage was comparable to that of alfalfa and higher than that of corn forage. The total soluble sugar (TSS) content in soybean fresh forage was higher than in alfalfa but lower than in corn forage. The hemicellulose content in soybean forage did not differ significantly from that in alfalfa but was lower than in corn. As compared to alfalfa, soybean fresh forage showed favorable values for dry matter digestibility (DMD), relative feed value (RFV), metabolizable energy (ME), and net energy for lactation (NEl), although these values were lower than those found in corn forage. Some authors mentioned various findings about the biochemical composition and nutritional value of whole plants of soybean. SHEAFFER et al. (2001) found that the forage quality of the herbage from soybean cultivars was characterized by the following indices: 12.5-16.2% CP, 44.7-54.1% NDF, 40.3-49.2% ADF. KOIVISTO et al. (2003) reported that the dry matter content and the nutrient composition of soybean cultivars harvested in October were: 177-225 g/kg DM with 10.0-15.3% CP, 38.4-45.0% NDF, 27.9-34.2% ADF, but soybean cultivars harvested in November, 194-247 g/kg DM, 12.5-16.3% CP, 65.3-82.5% NDF, 50.4-63.5% ADF, respectively.

Table 1.
The biochemical composition and nutritional value of fresh mass from *Glycine max*

Indices	*Glycine max*	*Medicago sativa* (third cut)	*Zea mays*
Crude protein, g/kg DM	175	141	84
Crude fibre, g/kg DM	310	383	248
Minerals, g/kg DM	86	90	52
Acid detergent fibre, g/kg DM	332	393	271
Neutral detergent fibre, g/kg DM	520	579	474
Acid detergent lignin, g/kg DM	61	66	48
Total soluble sugars, g/kg DM	91	69	336
Cellulose, g/kg DM	271	327	223
Hemicellulose, g/kg DM	188	186	203
Digestible dry matter, g/kg DM	630	583	678
Relative feed value	113	94	133
Digestible energy, MJ/ kg	12.41	11.57	13.28
Metabolizable energy, MJ/ kg	10.19	9.50	10.90
Net energy for lactation, MJ/ kg	6.21	5.51	6.91

UNDERSANDER et al. (2007) stated that soybean forage contained 11.4-19.5% CP, 21.4-30.0% CF, 43.8-47.5% NFE, 59.6-64.1% NDF, 39.6% ADF, 3.8-4.7% ADL, 31.5-37.2% Cel, 16.0% HC, 18.3-18.4 MJ/kg GE. DIAS et al. (2010) mentioned that the dry matter content and the nutritional quality of forage soybean was 287.7-370.5 g/kg DM, 7.00-8.77% ash, 10.9-15.4% CP, 44.6-55.50% NDF, 40.6-49.4% ADF. BOHNER et al. (2012) found that quality indices of soybean forages depending on the row spacing and growing stages were: 18.1-20.1% CP, 38.6-45.7% NDF, 28.0-30.0% ADF. ACIKGOZET al. (2013) reported that the herbage quality of soybean plants, depending on cultivars, was as follows: 16.3-16.8% CP, 36.2-36.9% NDF, 29.2-29.7% ADF, 62.6-63.6% TDN, and RFV=166.2-170.9. BLOUNT et al. (2013) reported that the dry matter content and nutrient value of soybean forage harvested mass were: 240-560 g/kg DM, 167-246 g/kg CP, 419-567 g/kg NDF, 58.2-61.4% IVDOM. LEE et al. (2014) mentioned that the forage quality of *Glycine soja* plants was 16.1-18.2% CP, 40.4-43.5% NDF, 27.5-31.7% ADF and RFV=139-158, but the forage quality of *Glycine max* 17.9-21.3% CP, 40.2-42.0% NDF, 26.1-30.0% ADF and RFV=146-161, respectively. ASEKOVA et al. (2016) found that the forage quality parameters of soybean plant were: 10.9-25.7% CP, 37.4-66.6% NDF, 22.6-38.1% ADF. HEUZE et al. (2016) remarked that the average feed value of soybean fresh mass was: 24.0% DM, 15.7% CP, 31.2% CF, 48.1% NDF, 31.2% ADF, 5.8% lignin, 9.3% ash, 14.8 g/kg Ca, 2.7 g/kg P, 64% DOM, 18.9 MJ/kg GE, 11.6 MJ/kg DE and 9.2 MJ/kg ME. NKOSI et al. (2016) remarked that the dry matter content and the chemical composition of soybean cultivars were as follows: 268.0-333.0 g/kg DM, 16.97-17.67% CP, 40.44-45.31% aNDF, 30.44-31.29% ADF, 6.46-6.75% ADL, 6.43-7.20% WSC, 17.07-18.21 MJ/kg GE. AVRAMENKO & NAUMOVA (2018) reported that the local soybean cultivars harvested in different stages of development contained 13.2-18.9% CP, 9.3-15.4% CF, 9.19-15.08% ash. TABACCO et al. (2018) found that whole soybean plants, depending on the stage of maturity, contained 22.0-37.4% DM, 16.7-25.0% CP, 3.1-6.8% fats, 35.4-47.0% NDF, 26.7-38.3% ADF, 5.7-9.1% ADL, 3.6-7.6% WSC, 1.2-8.1% starch, 8.0-11.6% ash. PEIRETTI et al. (2018) remarked that the herbage quality of soybean plant in the vegetative stage was 185.1-190.5 g/kg DM, 14.26-14.77% ash, 25.77-30.11% CP, 45.32-50.80% NDF, 32.77-35.65% ADF, 5.80-6.47% ADL, 876.5-880.7 g/kg IVTD, 17.5-18.1 MJ/kg GE, but in the generative stage: 181.9-204.4 g/kg DM, 9.25- 10.15% ash, 15.38-22.85% CP, 45.42-66.27% NDF, 37.18-42.54% ADF, 6.95-8.12% ADL, 775.9-842.1 g/kg IVTD, 18.0-18.5 MJ/kg GE. According to NADEEM et al. (2019), the nutritional quality indicators of soybean forage were: 19.86-27.70% CP, 32.03-33.86% NDF, 25.53-28.10% ADF, 4.80-6.33% lignin, 3.4-9.7% starch, 7.73-10.53% WSC, 7.89-10.53% ash, 656.6-666.7 g/kg TDN, 1.55-1.58 Mcal/kg NEl, RFV=213.33-223.33. GUREEVA & USHAKOVA (2020) mentioned that soybean contained 14.4% CP, 7.2% ash, 20.4% CF, 43.2% NFE, 128.0 g/kg DP, and 10.2 MJ/kg ME. OMOKANYE (2020) mentioned that the dry matter from tested soybean varieties contained 11.9-16.8% CP, 29.7-40.1% NDF, 23.7-31.9% ADF, 641-700 g/kg TDN, 1.45-1.61 Mcal/kg NEl, RFV= 149-220. ZANINE et al. (2020) reported that the harvested soybean genotypes contained 44.30-54.13% stems, 28.20-48.12% leaves; 0-25.6% pods, 156.9-180.8 g/kg DM and their biochemical composition was: 14.45-16.09% CP, 8.30-14.00% ash, 48.44-59.79% NDF, 41.74-49.60% ADF, 3.18-2.64% HC. THU HONG et al. (2020) revealed that the dry matter content and the chemical composition of soybean foliage was 239g/kg DM, 91.9% OM, 15.9% CP, 27.8% ADF, 64.0% NDF. IQBAL et al. (2021) mentioned that the nutritional quality of forage soybean was 18.21-21.9% CP, 1.70-1.97% EE, 23.0- 26.2% CF and 9.3-11.2% ash. ZAEEM et al. (2021) mentioned that the forage nutritional quality of monocropping soybean was: 18.4% CP, 14.9% ash, 43.9% NDF, 35.1% ADF, 6.7% WSC, while of monocropping corn respectively 10.7% CP, 6.4% ash, 57.7% NDF, 37.3% ADF, 15.6% WSC. As a result of previous research, ŢÎŢEI (2022) established that the concentration of nutrients in the dry matter of the green mass from *Glycine max* 'Clavera' was 178 g/kg CP, 286 g/kg CF, 94 g/kg ash, 310 g/kg ADF, 484 g/kg NDF, 49 g/kg ADL, 142 g/kg TSS, 261 g/kg Cel, 174 g/kg HC, with nutritive and energy value 68.6% DMD, 63.4% DOM, RFV = 124, 12.73 MJ/kg DE, 10.48 MJ/kg ME and 6.46 MJ/kg. THOMPSON et al. (2023) mentioned that the nutritive value of soybean cultivars was: 15.9-17.4% CP, 38.4-40.4% NDF, 29.4-32.2% ADF, 2.40-2.53 Mcal/kg DE, 554-574g/kg TDN. MOSSIE et al. (2024) mentioned that the chemical composition and *in vitro* dry matter digestibility of soybean genotypes was: 14.0-21.5% CP, 34.8-51.1% NDF, 22.7-37.4% ADF, 7.5-8.2% ADL and 599.8-904 g/kg IVDMD. SUN et al. (2024) revealed that the nutritional compositions and feeding quality of studied soybean varieties were: 22.8-31.8% CP, 0.5-2.5% EE, 36.3-61.4% NDF, 21.4-38.9%ADF, RFV=94-182. TASSONE et al. (2025) reported that soybean forage contained 199.9 g/kg DM with 15.39% CP, 1.53% EE, 7.21% NFC, 66.28% NDF, 42.54% ADF, 8.13%ADL, 9.52% ash, 675 g/kg DMD and RFV=95. YÜCESOY & GARIPOĞLU (2025) mentioned that the nutrient content of soybean plant according to different varieties was as follows: 18.17-20.48% CP, 39.49-42.16% NDF, 28.54-30.56% ADF.

CONCLUSIONS

The local soybean cultivar *Glycine max* 'Aura' demonstrated an optimal fresh biomass yield and favorable forage quality, making it a suitable option for inclusion in diverse livestock feeding systems. Additionally, it may serve as an excellent forecrop for cereals and grass forage crops, contributing to improved crop rotation and sustainable agricultural practices.

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