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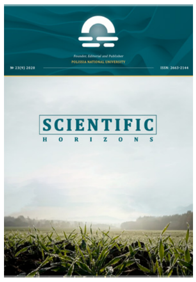

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Assessment of the genetic diversity of red fescue in the Western region of Ukraine

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Abstract. Red fescue (*Festuca rubra* L.) is a perennial plant of the cereal family (Poaceae), which is used as a fodder and lawn crop. Despite substantial research, the number of high-yielding varieties adapted to specific soil and climatic conditions is insufficient. Therefore, the examination of the genetic diversity of red fescue plants is the main stage in the creation of new varieties. The purpose of the study was to evaluate samples based on the main economic-biological characteristics and divide them into three groups of ripening for further use in breeding as a source of valuable traits. The study used general scientific (analysis, synthesis, experiment, description, observation, and comparison), field (phenological observations and accounting), and statistical methods. According to the results of the study, populations of different ecological and geographical origins created by different breeding methods were similar. The coefficients of variation in the parameters of the main features were in the

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range of 0.34-8.02% and depended on the biological and ecological characteristics of the samples. According to the duration of the growing season, the samples were divided into early-ripening (16 pcs.), medium-ripening (20 pcs.), and late-ripening (12 pcs.). When clustering by eight features, all samples were divided into three clusters. In the early-ripening group, substantial correlations were established between the duration of the growing season and 1000 grain weight, between plant height and seed yield, and between dry matter yield and leaf colour intensity. Positive associations between dry matter yield and regrowth intensity, between 1000 grain weight and leaf colour intensity were observed in the middle-ripening group. In the late-ripening group, reliable relationships were identified between plant height and tillering intensity, seed yield and 1000 grain weight, seed yield and leaf colour intensity, and dry matter yield and leaf colour intensity. The results obtained will be used in further breeding work when creating varieties of red fescue of various ripening groups with improved seed productivity, suitable for fodder and lawn use

Keywords: *Festuca rubra* L.*;* sample; yield; economic-biological characteristics; correlation coefficients; cluster

INTRODUCTION

Increasing the efficiency of using red fescue seeds is possible, primarily, by creating new varieties and conducting their seed production. Despite substantial research, the number of high-yielding varieties adapted to specific soil and climatic conditions is insufficient. In this regard, breeders need to create varieties with increased seed productivity, which would resist adverse environmental factors. It is important to conduct a preliminary examination and detailed assessment of samples of various ecological and geographical origins. All this indicates the relevance of the conducted study to solving the important scientific and practical issues mentioned above.

According to Braun *et al.* (2020), red fescue is a polymorphic species represented by several subspecies: *Festuca rubra L subsp. rubra, Festuca rubra L subsp. fallax (Thuill) Num., Festuca rubra L subsp. arenaria (Osbeck.) O. Schwarz., Festuca rubra L subsp. arctica (Hack.) Govor.* etc. Their wide geographical distribution is the result of adaptation to different environmental conditions and cultivation.

Central Europe is the centre of origin of species in the Festuca family. Red fescue is distributed in North America, Iceland, Minor and Central Asia, China, England, Lithuania, and Ukraine (Soreng *et al., 2015).* According to Mytsyk (2016), it is also located in the forest, forest-steppe, and high-altitude belts of the Caucasus and the Carpathians. Its specific thickets are present in forests, on the hummocks of swamps, and in their coastal zone. In the Steppe zone, it occurs mainly as an adventitious plant, including in its driest areas. It is absent in the modern forests of the Steppe Dnieper region.

Fescue is known for its shade tolerance, resistance to drought (Reiter *et al.,* 2017), salt (Friell *et al.,* 2013), and cold (Friell & Watkins, 2021), adaptability to infertile and acidic soils (pH 4.5-6.5). *Festuca rubra* is versatile due to its ability to withstand a wide range of mowing heights and grow in insufficiently fertile soils (Benfriha *et al.,* 2021). Ospina *et al.* (2015) presented a taxonomic review of the Festuca genus in Chile based on morphological and anatomical data, 19 species and two varieties were also examined.

Ostapets (2020) examined leaf blade colouration in samples of various fescue species. It was identified that the colour of the leaf blade is controlled by plasma genes that are transmitted through the maternal line, and can range from saturated green to green with a slight blue tint.

Varieties and populations of fescue differ in their morphological and biological characteristics. Mefti *et al.* (2016) and Georgieva *et al.* (2019) examined the genetic structure and biological resources of wild fescue forms when breeding for decorative properties and stability in specific soil-climatic conditions. According to Šurinová *et al.* (2019), temperature and precipitation are the best indicators of the genetic kinship of red fescue populations and can be important determining factors for population differentiation.

Afkar *et al.* (2022) evaluated genetic diversity in 22 populations of three Festuca species (*Festuca arundinacea*, *F. rubra* and *F. ovina*) using the seed protein electrophoresis model. Studies showed that there is a high level of genetic diversity within a species, not between species. Cluster analysis was used to evaluate populations. Researchers recommend using the best samples as parent components for hybridisation. Ustariz *et al.* (2022) examined 43 populations of Festuca species (in Bolivia (drought and low temperatures)) to effectively preserve and reproduce genetic diversity. The study indicated a low level of genetic differentiation between populations. The authors developed EST-SSR markers that are recommended for use in assessing the genetic diversity of Bolivian fescue (Ustariz *et al.,* 2022).

Shahabzadeh *et al.* (2020) evaluated the genetic diversity and structure of 90 high-grade fescue populations and varieties using ISSR and EST-SSR markers. The samples were classified according to the area of feed and lawn use and recommended for use in variety improvement programmes in various areas of use. All these studies confirm that the formation of collections for creating the source material of red fescue involves a preliminary examination of samples by the main characteristics and their effective use in the breeding process by yield and other economic-biological characteristics (Baistruk-Hlodan *et al.*, 2019).

The purpose of the study was to examine the selection material of *Festuca rubra* in the conditions of the Western region of Ukraine. In addition to the characteristics of lawn and fodder use, samples should be characterised by high seed productivity. The main tasks were to evaluate samples by biological and economic characteristics, divide samples into ripening groups by the duration of the growing season, and establish relationships between the main characteristics.

MATERIALS AND METHODS

The study was conducted on the experimental basis of the Precarpathian Scientific and Research Department of the Institute of Agriculture of the Carpathian region of the National Academy of Agrarian Sciences in 2016-2020. The soil of the experimental field is typical for the region, sod-medium podzolic gumbo medium-acidic loamy formed on diluvial deposits drained using clay tube drainage.

The climate of the Western region of Ukraine is moderately warm and humid. It is characterised by a long spring, non-hot summers, a fairly long autumn, and relatively mild winters. Over the years of the study, there were substantial differences in the amount of precipitation and temperatures during the summer months from the perennial average data, which allowed assessing growth and development indicators of *Festuca rubra* in a more diverse way.

The object of the study was 48 samples of red fescue of various ecological and geographical origins, obtained by various methods of selection (mass, individual, group) and intraspecific hybridisation. The samples are provided with the numbers of the Institute of Agriculture of the Carpathian region of the National Academy of Agrarian Sciences and the numbers of the National Catalogue of Ukraine (Table 1).

Table 1. *Samples of Festuca rubra L, institution code, national catalogue number, and total average economic-biological characteristics, clusters*

Institution registration number, PFZ	National catalogue number	Sample	Duration of the growing season, days	Plant height, cm	Grain yield per plant	Dry matter, m^2	1000 grain weight	Tillering intensity	Leaf colour intensity	Regrowth after mowing	Cluster members (membership)
1	2	3	4	5	6	7	8	9	10	11	12
		early ripening group									
01548	UJ 1300370	ID from No. 925	97	56.8	2.3	0.47	0.80	3	4	3	1
00806	UJ 1300177	No. 331	95	57.9	4.1	0.51	0.94	4	3	4	2
00594	UJ 1300254	129 K	97	59.3	2.1	0.61	0.90	3	4	2	2
00587	UJ 1300253	DP	96	57.2	2.8	0.39	0.79	3	4	3	1
01545	UJ 1300334	MD from No. 1135	93	58.2	3.4	0.54	1.10	3	3	2	2
01542	UJ 1300331	ID from No. 853	95	59.3	5.6	0.55	1.11	3	3	4	2
01541	UJ 1300330	MD from No. 978	92	56.1	6.1	0.42	1.10	4	4	3	3
00936	UJ 1300280	MD from No. 3	94	57.2	4.3	0.56	0.99	2	3	3	2
01776	UJ 1300337	Eid from Hoverla	97	56.4	5.7	0.63	0.78	3	2	4	1
01154	UJ 1300291	MD from Malomice/ZG	93	60.0	3.2	0.52	0.99	4	3	4	2
01134	UJ 1300288	ID with DP	95	57.2	4.1	0.38	0.77	4	3	2	1
01007	UJ 1300285	MD with Gludas	97	59.2	5.0	0.47	0.81	3	3	2	1
02034	UJ 1300392	DP	97	57.4	4.9	0.51	0.91	3	2	2	1
01547	UJ 1300371	DP	96	55.3	6.0	0.52	0.79	4	3	2	1
00742	UJ 1300184	Hoverla	97	56.0	7.0	0.39	0.97	4	4	2	3
01397	UJ 1300390	DP	93	56.4	5.3	0.45	1.10	2	4	4	2
		medium-ripening group									
00804	UJ 1300175	Gludas	102	57.4	4.3	0.58	1.05	3	4	3	2
01540	UJ 1300373	GP No. 854 x No. 925	98	56.9	3.6	0.39	1.02	3	3	3	1
00935	UJ 1300279	Selection from No. 2	103	56.1	4.1	0.47	1.00	4	4	2	3
00925	UJ 1300278	Selection from DP	101	58.2	5.1	0.54	0.98	3	3	3	2

Table 1, Continued

Institution registration number, PFZ	National catalogue number	Sample	Duration of the growing season, days	Plant height, cm	Grain yield per plant	Dry matter, m^2	1000 grain weight	Tillering intensity	Leaf colour intensity	Regrowth after mowing	Cluster members (membership)
1	2	3	4	5	6	7	8	9	10	11	12
00854	UJ 1300277	DP	99	59.3	6.4	0.52	0.87	4	3	4	2
00853	UJ 1300276	DP	100	57.1	4.7	0.49	0.99	4	4	4	2
01739	UJ 1300154	Yanka	101	60.1	5.4	0.37	1.01	3	3	2	3
00805	UJ 1300176	No. 257	101	58.6	3.6	0.36	0.96	3	4	2	3
01543	UJ 1300332	MD from No. 1363	101	54.9	4.2	0.39	0.88	2	2	2	1
01214	UJ 1300300	Varius	99	54.1	4.4	0.49	0.91	3	2	3	1
01136	UJ 1300290	MD from No. 854	101	59.2	5.1	0.54	1.05	2	4	3	2
01008	UJ 1300286	RGD from No. 257	98	56.6	6.3	0.56	1.06	3	3	4	2
00940	UJ 1300284	MD from No. 8	101	55.7	4.7	0.47	0.94	3	3	3	1
00017	UJ 1300029	Malomice/ZG	103	58.4	6.1	0.39	0.96	4	3	3	3
00018	UJ 1300028	Lidzbark Warw	98	56.3	7.8	0.52	1.04	4	4	3	3
00015	UJ 1300030	Nasiezne/KS	100	57.9	4.3	0.55	1.01	5	4	4	2
00016	UJ 1300081	Exp.S-250-11	101	57.1	5.6	0.39	0.99	4	3	3	3
02045	UJ 1300393	DP	102	56.9	5.1	0.41	0.95	4	4	4	2
01279	UJ 1300388	DP	99	58.9	3.5	0.51	0.75	5	3	3	2
01304	UJ 1300389	DP	100	57.1	8.3	0.53	0.68	4	3	3	1
late-ripening group											
00937	UJ 1300281	MD from No. 4	104	55.6	2.9	0.47	0.73	3	4	4	1
00938	UJ 1300282	MD from No. 6	109	59.1	4.3	0.38	0.70	3	4	4	1
01538	UJ 1300374	ID from No. 1008	107	59.4	5.6	0.51	0.89	4	3	3	2
01155	UJ 1300292	MD from Lidzbark Warw	104	59.3	4.7	0.60	0.93	4	3	3	2
01544	UJ 1300333	MD from No. 1007	104	56.4	3.8	0.42	0.94	2	4	3	1
01363	UJ 1300314	MD from Varius	107	59.7	4.9	0.43	1.02	4	4	3	3
01156	UJ 1300293	MD from Kalnica/KS	104	59.3	6.8	0.52	1.03	4	2	4	2
01135	UJ 1300289	MD from No. 853	108	58.1	4.7	0.60	0.98	3	3	3	2
01009	UJ 1300287	ID from No. 331	104	55.4	5.4	0.55	0.99	2	3	3	1
00939	UJ 1300283	MD from No. 7	107	57.8	3.9	0.58	1.01	4	3	4	2
01157	UJ 1300294	MD from Nasiezne/KS	105	59.1	6.0	0.43	1.14	3	3	3	3
00014	UJ 1300024	Kalnica/KS	105	60.5	5.4	0.48	1.07	3	3	3	3

Notes:* *Tillering Intensity: 1 – very low; 2 – low; 3 – medium; 4 – high; 5 – very high; *Leaf colour Intensity: 1 – very light; 2 – light; 3 – medium; 4 – dark; 5 – very dark; *regrowth after mowing: 1 – very low; 2 – low; 3 – medium; 4 – high; 5 – very high*
***Source:** compiled by the authors using descriptors for red fescue (GRIN Czech Release 1.10.3)*

The study used general scientific (analysis, synthesis, experiment, description, observation, and comparison), field (phenological observations and accounting), and statistical methods. The samples were examined in a collection nursery. Plot area was 2 m^2. 8 bushes were planted on each plot. The repetition was threefold. Phenological observations were conducted throughout the growing season in accordance with (Formation and preservation of genetic diversity of forage and lawn grasses in Precarpathia, 2015). The journal of observations noted the features of growth and development and the appearance of plants according to the descriptors for red fescue (GRIN Czech Release 1.10.3).

The duration of the growing season between the earliest variety of red fescue and the latest was 18 days. The variety samples were divided into three groups: early-ripening (the duration of the growing season is 92-97 days), medium-ripening (98-103 days), and late-ripening (104-109 days). 16 samples were assigned to the early-ripening group, 20 samples to the medium-ripening group, and 12 – to the late-ripening group.

Evaluation of red fescue was conducted according to the following criteria: tillering intensity, leaf colour intensity, regrowth intensity, plant height, dry matter yield, seed yield, and 1000 grain weight. The yield of green mass was calculated by repeatedly mowing four bushes on the site at the height of 13-15 cm of the herbage. Hay yield from the green mass was determined by test sheaves weighing 0.1 kg, selected after mowing and dried to a constant mass. Grains were collected by hand by threshing, cleaning, and weighing them separately from each plant.

Statistical data processing was performed using correlation and variance analysis methods using the TIBCO Statistica 13.5.0.17 software package (1984-2018 Tibco Software Inc.).

RESULTS AND DISCUSSION

The family of cereals (Poaceae Barnh.) is the most widespread on the globe, it occupies 60-90% of the total composition of natural herbal communities. About 1000 species are known from the cereal family. The Festuca genus is the most diverse in the Poaceae family (about 450 species worldwide). It is used for feed, turf, landscape, decorative, and bioenergetic purposes. In total, 170 species and more than 50 subspecies of the Festuca genus were described in the European flora. However, only for less than 10 species, practical importance was determined and varieties were created. Three varieties are widely used: Meadow fescue (*Festuca pratensis* Huds.), tall fescue (*Festuca arundinacea* Schreb.), and red fescue (*Festuca rubra* L.).

The effectiveness of breeding work with representatives of the *Festuca* genus is determined by numerous factors, including the area and criteria of use. The value of *F. rubra* as a forage and lawn grass used in Europe requires a better understanding of the diversity of wild ecotypes of the species due to the possibility of using them in breeding programmes. Source material is the main factor. Growing and improving grass varieties requires constant updating of the source material. Ecotypes identified in natural habitats and thus best adapted to soil and climatic conditions are a natural source of genetic diversity of species. Therefore, they should serve as the main source of enrichment of the genetic base of cultivated perennial grasses.

Economic-biological characteristics play a substantial role in the introduction of agricultural plants into production. The main ones are the duration of the growing season, the intensity of tillering, leaf colour, regrowth after mowing, the height of plants, the yield of dry matter, seed yield, and the 1000 grain weight. In the early-ripening group, the lowest coefficient of variation was based on the duration of the growing season (0.46%), and the highest – on seed yield (8.02%). All the examined features were probable (p<0.05) (Table 2).

Table 2. *Parameters of traits of red fescue of the early-ripening group (n=16)*

Traits	Minimum value, *Min*	Maximum value, *Max*	Average indicator Mean	F-Test	Standard error Std. Error. (SE)	Standard deviation SD (p=0.05)	Coefficient of variation CV (%)
Duration of the growing season, days	92.00	97.00	95.33	*	0.44	1.77	0.46
Plant height, cm	55.30	60.00	57.50	*	0.34	1.38	0.59
Grain yield, g	2.10	7.00	4.49	*	0.36	1.45	8.02
Dry matter yield, g	0.38	0.63	0.50	*	0.02	0.08	4.00
1000 grain weight, g	0.77	1.11	0.93	*	0.03	0.13	3.23
Tillering intensity	2.00	4.0	3.25	*	0.17	0.68	5.23
Colour intensity	2.00	4.0	3.25	*	0.17	0.68	5.23
Regrowth intensity	2.00	4.0	2.87	*	0.22	0.89	7.67

Source: *calculated by the authors using ANOVA software*

The combination of different economically valuable traits in one variety is a complex and poorly understood problem, so the examination of the correlation structure is of practical interest. Determining the correlation between plant productivity traits allows for establishing some patterns in crop formation and identifying valuable source material when a direct assessment of the desired trait is somewhat difficult. Of all the examined correlations between the characteristics of red fescue samples, only between the duration of the growing season and the mass of 1000 seeds (-0.722); between plant height and seed yield (-0.490); between dry matter yield and leaf colour intensity (-0.501) were negative and reliable (Table 3).

Table 3. *Correlation coefficients between morpho-biological characteristics of red fescue plants of the early-ripening group*

Traits	Plant height, cm	Grain yield, g	Dry matter yield, g	1000 grain weight, g	Tillering intensity	Colour intensity	Regrowth intensity
Duration of the growing season, days	-0.054	-0.041	0.121	**-0.722**	-0.001	-0.165	-0.362
Plant height, cm	1	**-0.490**	0.340	0.185	-0.076	-0.140	0.130
Grain yield, g	-	1	-0.159	0.224	0.197	-0.200	0.020
Dry matter yield, g	-	-	1	0.071	-0.321	**-0.501**	0.228
1000 grain weight, g	-	-	-	1	-0.184	0.195	0.308
Tillering intensity	-	-	-	-	1	-0.001	-0.165
Colour intensity	-	-	-	-	-	1	-0.055
Regrowth intensity	-	-	-	-	-	-	1

Source: *calculated by the authors using ANOVA software*

Using these traits is recommended when creating early-ripening high-yielding varieties. The samples of the medium-ripening group differed slightly in basic indicators from the samples of the early-ripening group. The lowest was the coefficient of variation based on the duration of the growing season (0.34%), and the highest – grain yield (5.65%). All examined features were substantial ($p<0.05$) (Table 4).

Table 4. *Parameters of traits of red fescue of the medium-ripening group (n=20)*

Traits	Minimum value, *Min*	Maximum value, *Max*	Average indicator Mean	F-Test	Standard error Std. Error. (SE)	Standard deviation SD (p=0.05)	Coefficient of variation CV (%)
Duration of the growing season, days	98.00	103.00	100.40	*	0.34	1.54	0.34
Plant height, cm	54.10	60.10	57.34	*	0.32	1.52	0.56
Grain yield, g	3.50	8.30	5.13	*	0.29	1.32	5.65
Dry matter yield, g	0.36	0.58	0.47	*	0.02	0.07	4.26
1000 grain weight, g	0.68	1.06	0.96	*	0.02	0.10	2.08
Tillering intensity	2.00	5.00	3.50	*	0.18	0.83	5.14
Colour intensity	2.00	4.00	3.30	*	0.15	0.66	4.55
Regrowth intensity	2.00	4.00	3.05	*	0.15	0.69	4.92

Source: *calculated by the authors using ANOVA software*

Of all the correlations examined, only between dry matter yield and regrowth intensity (0.497); between 1000 grain weight and leaf colour intensity (0.431), the relationship was positive and reliable (Table 5).

Table 5. *Correlation coefficients between morpho-biological characteristics of red fescue plants of the medium-ripening group*

Traits	Plant height, cm	Grain yield, g	Dry matter yield, g	1000 grain weight, g	Tillering intensity	Colour intensity	Regrowth intensity
Duration of the growing season, days	0.119	-0.199	-0.299	0.097	-0.083	0.240	-0.370
Plant height, cm	1	0.055	-0.011	0.023	0.184	0.340	0.038
Grain yield, g	-	1	0.259	-0.181	0.150	-0.023	0.254
Dry matter yield, g	-	-	1	0.003	0.155	0.221	**0.497**
1000 grain weight, g	-	-	-	1	-0.310	**0.431**	0.058
Tillering intensity	-	-	-	-	1	0.290	0.417

Table 5, Continued

Traits	Plant height, cm	Grain yield, g	Dry matter yield, g	1000 grain weight, g	Tillering intensity	Colour intensity	Regrowth intensity
Colour intensity	-	-	-	-	-	1	0.198
Regrowth intensity	-	-	-	-	-	-	1

Source: *calculated by the authors using ANOVA software*

In the group of late-ripening plants, the lowest coefficient of variation was based on the duration of the growing season (0.50%) and the highest – tillering intensity (6.77%). All the examined features were probable ($p<0.05$) (Table. 6).

Of all the correlations examined, only between plant height and tillering intensity (0.632) and between grain yield and 1000 grain weight (0.622) were positive and reliable. Between grain yield and colour intensity (-0.756), between dry matter yield and colour intensity (-0.613), the relationship was negative and substantial (Table 7). Therefore, these characteristics should be considered at the next stages of breeding when creating lawn varieties.

Table 6. *Parameters of traits of red fescue of the late-ripening group (n=12)*

Traits	Minimum value, *Min*	Maximum value, *Max*	Average indicator, Mean	F-Test	Standard error Std. Error. (SE)	Standard deviation SD (p=0.05)	Coefficient of variation CV (%)
Duration of the growing season, days	104.00	109.00	105.67	*	0.53	1.83	0.50
Plant height, cm	55.40	60.50	58.31	*	0.48	1.68	0.82
Grain yield, g	2.90	6.80	4.87	*	0.31	1.06	6.37
Dry matter yield, g	0.38	0.60	0.50	*	0.02	0.07	4.00
1000 grain weight, g	0.70	1.14	0.95	*	0.04	0.13	4.21
Tillering intensity	2.00	4.00	3.25	*	0.22	0.75	6.77
Colour intensity	2.00	4.00	3.25	*	0.18	0.62	5.54
Regrowth intensity	3.00	4.00	3.33	*	0.14	0.49	4.20

Source: *calculated by the authors using ANOVA software*

Table 7. *Correlation coefficients between morpho-biological characteristics of red fescue plants of the late-ripening group*

Traits	Plant height, cm	Grain yield, g	Dry matter yield, g	1000 grain weight, g	Tillering intensity	Colour intensity	Regrowth intensity
Duration of the growing season, days	0.358	-0.114	-0.120	-0.255	0.264	0.240	0.135
Plant height, cm	1	0.538	-0.098	0.323	**0.632**	-0.299	-0.158
Grain yield, g	-	1	0.094	**0.622**	0.238	**-0.756**	-0.272
Dry matter yield, g	-	-	1	0.243	0.287	**-0.613**	-0.099
1000 grain weight, g	-	-	-	1	0.087	-0.564	-0.487
Tillering intensity	-	-	-	-	1	0.340	0.245
Colour intensity	-	-	-	-	-	1	0.000
Regrowth intensity	-	-	-	-	-	-	1

Source: *calculated by the authors using ANOVA software*

However, the examination of the main economic-biological traits by ripening groups does not provide sufficient information on samples. Ultimately, the selected numbers may be inferior in one attribute to another. Therefore, to establish the similarity of samples by individual groups of traits and the totality and degree of genetic divergence, a cluster analysis was performed, which allowed classifying the breeding material of red fescue. Using this method, based on Euclidean distance coefficients for eight morpho-biological features, a natural relationship was established between 48 samples of different ecological-geographical origins. The dendrogram is constructed using the Euclidean metric and the single-link method. This method combines two samples that are most similar to each other. At the next iteration, they are joined by a sample with the maximum similarity of one of them, which leads to the formation of a cluster. Euclidean distances are used as a measure of genetic divergence to distinguish between genetically close groups of samples. The distribution of samples into clusters is shown in Figure 1, it differed from the division of samples by the duration of the growing season. The first cluster includes 16 samples, the second – 21 samples, and the third – 11 samples (Table 1, Fig. 1).

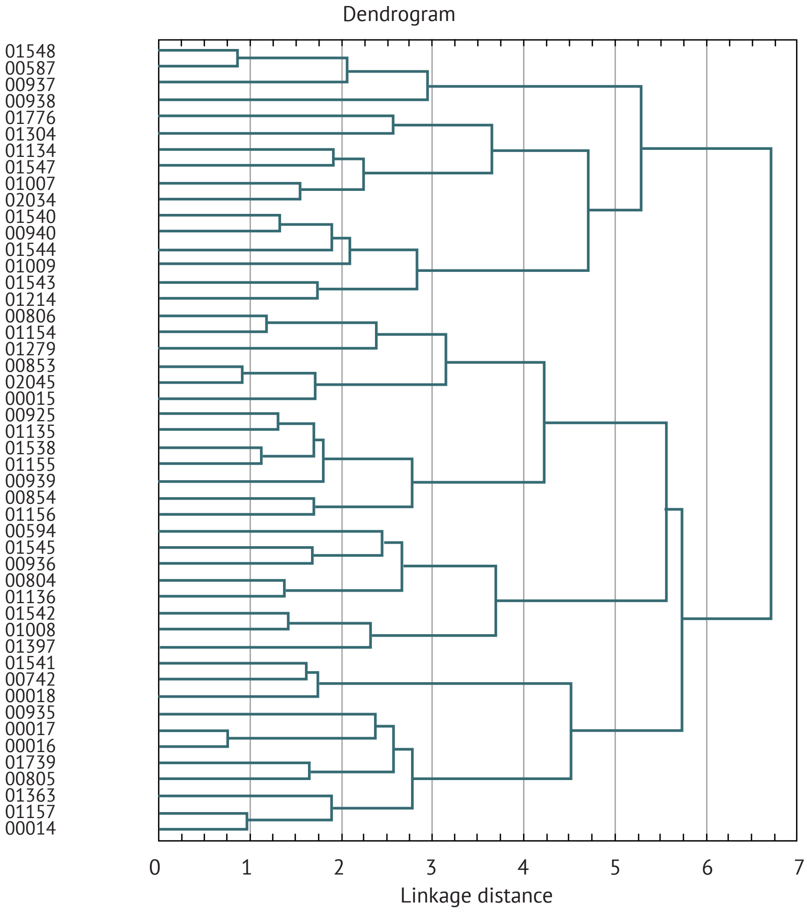

Figure 1. *Clustering of red fescue samples by eight morpho-biological characteristics (horizontal – Euclidean distances, vertical – samples)*

Populations of red fescue have morpho-biological plasticity and high adaptive capabilities, which opens up prospects for finding the most adapted forms to specific soil and climatic conditions. One of the important factors that determines the success of introduction and contributes to the cultivation of red fescue varieties is high grain productivity.

A number of researchers examined samples of red fescue according to various traits and identified the best of them. Angelov & Bednarska (2018) conducted a study of natural populations of species of the Festuca genus from Bulgaria, calculated the values of genetic identity for paired comparisons, and determined the kinship of all the examined species.

Bitarafan *et al.* (2019) investigated grain yield and lodging of red fescue samples for three years. A positive correlation was identified between the intensity of colouration and lodging and a negative effect of lodging on grain yield. According to Braun *et al.* (2020), red fescue is characterised by substantial intraspecific variability of biological parameters.

Eleven traits in samples of red fescue were evaluated by Iwańska *et al.* (2019). Based on multivariate analysis, i.e. hierarchical cluster analysis and the component analysis principle, the authors identified and described groups of varieties and evaluated the relationships between traits. The traits that most correlate with grain productivity are identified: plant height, grain yield, plant growth rate, leaf width, and time before the start of earing. Samples of feed and lawn use are highlighted.

Stukonis *et al.* (2015) examined 38 samples of red fescue in Lithuania, which were collected in different bioclimatic regions of Ukraine and Lithuania. Samples were evaluated for 16 morpho-anatomical features. The authors identified that the Ukrainian and Lithuanian populations differed in leaf structure. As a result of the studies, 7 promising populations were identified (6 populations from Ukraine) based on the number of grains per plant and plant height.

Similar studies of the source material of red fescue in the conditions of the Precarpathian region were conducted by Konyk (2016). Sources of valuable traits that are recommended to be used in further breeding work are highlighted. It is established that grain productivity is affected by such traits as mass of 1000 grains, number of grains in the inflorescence, and mass of grains per ear.

Baistruk-Hlodan *et al.* (2019) evaluated 37 samples of red fescue under Precarpathian conditions. Standard samples and the best samples are selected based on the following characteristics: duration of the growing season, winter hardiness, plant height, regrowth rate after mowing, yield of green mass, dry matter, and grain. These samples are recommended to be used as a starting material for creating feed varieties.

Using molecular markers and phenotypic measurements Stojanova *et al.* (2018) examined the adaptive potential of 11 populations of *Festuca rubra*. The authors proved that quantitative genetic differentiation between populations is caused by climate change.

Benfriha *et al.* (2021) evaluated the genetic diversity of fescue ecotypes from different regions of Algeria. Wild populations were compared with varieties, as a result of which, 743 markers were isolated, the variation within the population was high and amounted to 86%.

All this suggests that in the studies, the authors used a different source and its response to different growing conditions. Analysing the results obtained, it can be argued that the formation and examination of the collection of red fescue is an important stage in the breeding process. This enables the creation of a database of economic-morphological characteristics, which at the next stages of breeding should be used when creating new source material (selection, hybridisation) and new varieties of forage and lawn use. Ultimately, the requirements for them are different. Therefore, work on the selection of grass varieties for lawns, pastures, and hayfields is conducted in radically opposite directions. A good fodder variety should have rapid and intense growth and the ability to provide the maximum amount of high-quality green mass. Varieties for lawns, on the contrary, should provide: good tillering, rapid covering of the site surface, slow regrowth after mowing, juicy, beautiful greenery after mowing, have an attractive leaf mass.

CONCLUSIONS

Based on the results of the study conducted in the Precarpathian Scientific and Research Department of the Institute of Agriculture of the Carpathian region, an information database of the main economic-biological characteristics of 48 samples of red fescue and a working collection were formed. Based on the analysis of eight morpho-biological features, the samples were divided into three clusters. According to the duration of the growing season, the breeding numbers of red fescue were divided into three groups of ripening: early-ripening, medium-ripening, and late-ripening.

It was identified that the average height of plants in the early-ripening group is 57.5 cm, in the medium-ripening group – 57.34 cm, and in the late-ripening group – 58.31 cm. In terms of grain yield, samples of the medium-ripening group had the best indicators – 5.13 g per plant, samples of the early-ripening group had the lowest indicators – 4.49 g per plant. In terms of dry matter yield, samples of all ripening groups were at the same level – 0.50; 0.47; 0.50 g per plant. By 1000 grain weight, the best indicators were identified in samples of the early-ripening group – 0.93 g.

Samples with high tillering intensity were highlighted – PFZ00806, PFZ01541, PFZ01154, PFZ01134, PFZ01547, PFZ00742, PFZ00953, PFZ00854, PFZ00853, PFZ00017, PFZ00018, PFZ00016, PFZ02045, PFZ01304, PFZ01538, PFZ01155, PFZ01363, PFZ01156, PFZ00939. The intensity of leaf colour in samples of all ripening groups varied from light (2) to dark (4).

According to the rate of regrowth after mowing, samples with high indicators were identified – PFZ00806, PFZ01542, PFZ01778, PFZ01154, PFZ01397, PFZ00854, PFZ00853, PFZ01008, PFZ00015, PFZ02045, PFZ00937, PFZ00938 (for feed use) and low – PFZ00594, PFZ01545, PFZ01134, PFZ01007, PFZ02034, PFZ01547, PFZ00742, PFZ00935, PFZ01739, PFZ00805, PFZ01543 (for lawn use).

The samples used in the study are recommended to be used in further breeding work as parent components when creating varieties and new source material of red fescue of different ripening groups and different areas of use.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Оцінка генетичного різноманіття костриці червоної в умовах Західного регіону України

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Анотація. Костриця червона (*Festuca rubra* L.) – багаторічна рослина родини злакових (Poaceae), яка використовується як кормова та газонна культура. Незважаючи на значний обсяг досліджень, кількість високоврожайних сортів адаптованих до конкретних грунтово-кліматичних умов недостатня. Тому вивчення генетичного різноманіття рослин костриці червоної є основним етапом при створенні нових сортів. Метою дослідження було оцінити зразки за основними господарсько-біологічними ознаками та поділити їх на три групи стиглості для подальшого використання в селекції як джерела цінних ознак. У дослідженні використовували загальнонауковий (аналіз, синтез, дослід, опис, спостереження і порівняння) польовий (фенологічні спостереження та обліки) та статистичний методи. За результатами досліджень, популяції різного еколого-географічного походження та створені різними методами селекції були подібними. Коефіцієнти варіації за параметрами основних ознак знаходилися в межах 0,34-8,02 % і залежали від біологічно-екологічних особливостей зразків. За тривалістю вегетаційного періоду зразки було поділено на ранньостиглі (16 шт.), середньостиглі (20 шт.) та пізньостиглі (12 шт.). При кластеризації за вісьмома ознаками всі зразки було поділено на три кластери. В ранньостиглій групі між «тривалістю вегетаційного періоду» та «масою 1000 насінин», між «висотою рослини» та «врожайністю насіння», між «врожайністю сухої речовини» та «інтенсивністю забарвлення листя» встановлено достовірні кореляційні зв'язки. Позитивні зв'язки між «врожайністю сухої речовини» та «інтенсивністю відростання», між «масою 1000 насінин» та «інтенсивністю забарвлення листя» відмічали у середньостиглій групі. У пізньостиглій групі між «висотою рослини» та «інтенсивністю кущення», між «врожайністю насіння» та «масою 1000 насінин», між «врожайністю насіння» та «інтенсивністю забарвлення листя», між «врожайністю сухої речовини» та «інтенсивністю забарвлення листя» були виявлені достовірні зв'язки. Отримані результати будуть використовуватись в подальшій селекційній роботі при створенні сортів костриці червоної різних груп стиглості із покращеною насіннєвою продуктивністю, придатні для кормового і газонного використання

Keywords: *Festuca rubra* L.; зразок; врожайність; господарсько-біологічні ознаки; коефіцієнти кореляції; кластер