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Multivariate characteristics of selected grass varieties for seed production

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Abstract: Data were obtained in a field experiment carried out at Plant Breeding and Acclimatization Institute Radzikow (central Poland) in 2009–2011. The aim of this study was a multivariate evaluation of 13 advanced lines and cultivars of *Festuca rubra*, taking into account traits important in seed production. Eleven traits of the grasses and plant resistance to diseases were evaluated. On the basis of multivariate analyses, i.e. hierarchical cluster analysis and principal component analysis, groups of varieties were separated and described, relationships between the traits were evaluated as well. The traits with the biggest influence on multivariate diversity of examined varieties were correlated with the first principal component i.e. height of plants, seeds yield, growth rate of plants, leaf width and time to beginning of earing.

Keywords: *Festuca rubra*; multivariate analysis; principal component analysis

Festuca rubra L. is an important grass species used both as a fodder plant and as a turf plant for the production of sports, decorative and technical lawns. The assessment of usefulness of grasses should take into account many traits, including plant growth, disease resistance, and seed yield, which is particularly important for seed production. Comprehensive assessment of varieties should therefore cover a large number of traits, which can be carried out using statistical multivariate methods. Simultaneous incorporation of several traits in the analysis requires the use of statistical multivariate methods that allow to classify and characterize varieties and indicate which varieties are most valuable in terms of all important traits (Mefti *et al.* 2016). Such methods allow to distinguish groups of similar varieties and to identify groups which may be valuable as breeding material. Commonly used principal component analysis (PCA) and cluster analysis are often used to distinguish groups of varieties and characterize them (Veronesi & Falcinelli 1988; Charmet *et al.* 1994).

The aim of the research was to evaluate the multivariate diversity of selected *Festuca rubra* varieties and advanced lines. In addition, the relationship between the tested traits was assessed. For this purpose, multivariate statistical analyses were carried out on data from the experiment conducted in years 2009–2011. Thirteen advanced lines and cultivars of *F. rubra* were examined.

The field experiment was designed as a randomized complete block design with three replications. The size of the plots was 1 m^2; 500 seeds per 1 m^2 were sown in rows spaced by 30 cm. The experiment was carried out according to the COBORU (Polish Research Centre for Cultivar Testing) research methodology (Domański *et al*. 1979) and the performance characteristics were determined according to the

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Table 1. Analysed traits in *Festuca rubra* and their abbreviations

Abbreviation	Description of the trait
LW	leaf width (mm)
GA	general aspect of plants in scale from 1 to 9
S	sodding plant cover in scale from 1 to 9
GR	growth rate of plants in scale from 1 to 9
BE	beginning of earing (days from 1st April)
L	lodging of plants in scale from 1 to 9
NG	number of generative shoots
HP	height of plants at maturity (cm)
RM	resistance for mildew in scale from 1 (heavy disease) to 9 (healthy plants)
RR	resistance for rust (*Puccinia graminis)* in scale from 1 (heavy disease) to 9 (healthy plants)
RLB	resistance for leaf blight (*Helmintosporiosis*) in scale from 1 (heavy disease) to 9 (healthy plants)
Yield	seeds yield (quintal per ha)

IHAR (Plant Breeding and Acclimatization Institute, Radzików, Poland) method (Prończuk 1993) and COBORU (Domański 1992). Eleven morphological traits and plant resistance were evaluated based on 10 plants randomly selected from each plot. The tested traits were evaluated on a nine-point scale (1 – bad to 9 – most favourable). The individual traits are given in Table 1.

Basic statistical estimates were calculated to characterize average values and variability of the traits. Two-way analysis of variance and multiple comparison of means using Tukey's procedure was performed at significance level of 0.05. Multivariate analysis was also carried out for multivariate classification of the examined objects (varieties). Correlations between pairs of trais were evaluated using Pearson correla-

Table 2. Means of examined traits for particular varieties and values of Tukey's HSD (α = 0.05) for comparisons of means between *Festuca rubra* varieties

Variety	LW[a]	GA	S	GR	BE	L	NG	HP	RM	RR	RLB	Yield
Forage varieties												
R-18	2.67	4.89	7.44	7.33	46.2	5.44	581	80.1	6.89	6.78	8.22	12.9
R-19	2.44	5.11	7.56	7.67	46.8	4.89	928	83.9	7.44	6.89	8.11	9.6
R-20	3.22	4.56	7.33	7.33	46.7	4.89	927	81.1	7.11	6.22	8.44	10.6
R-21	2.89	4.33	7.22	7.11	47.7	4.78	735	83.1	7.44	6.56	7.89	11.6
Juka	3.22	4.67	6.78	7.56	46.0	4.56	720	85.0	7.44	6.56	8.22	11.4
Reda	2.44	4.89	6.78	7.44	45.9	4.67	864	85.6	7.00	6.44	8.11	12.0
Lawn varieties												
NIB-2406	2.22	5.22	7.44	5.89	42.8	5.78	1160	74.8	7.00	5.67	8.44	9.7
NIB-245	2.00	4.78	7.89	5.89	44.3	5.22	947	73.6	7.56	6.22	8.44	9.7
833 × 24w	2.33	4.44	6.33	5.22	43.1	6.33	1169	63.1	7.44	6.00	8.67	7.6
833 × 24p	2.11	4.11	6.11	4.56	44.7	7.67	902	63.7	7.89	6.11	8.22	7.4
24 × Barcrown	2.00	5.22	6.00	5.22	42.0	6.89	1232	69.0	7.11	6.89	8.22	8.8
Nimba	2.11	5.56	6.33	5.00	42.2	7.33	1009	63.6	8.00	6.67	8.44	8.9
Areta	3.56	4.89	6.89	7.00	44.4	5.89	751	78.1	8.33	6.78	8.44	13.2
Tukey HSD	0.73*	1.10*	1.07*	1.31*	1.90*	1.60*	607*	10.5*	1.30*	1.12*	0.94	2.96*

*indicate occurrence of at least one statistically significant difference between varieties; [a]LW – leaf width; GA – general aspect of plants; S – sodding plant cover; GR – growth rate of plants; BE – beginning of earing; L – lodging of plants; NG – number of generative shoots; HP – height of plants; RM – resistance for mildew; RR – resistance for rust; RLB – resistance for leaf blight; yield – seeds yield (quintal per ha)

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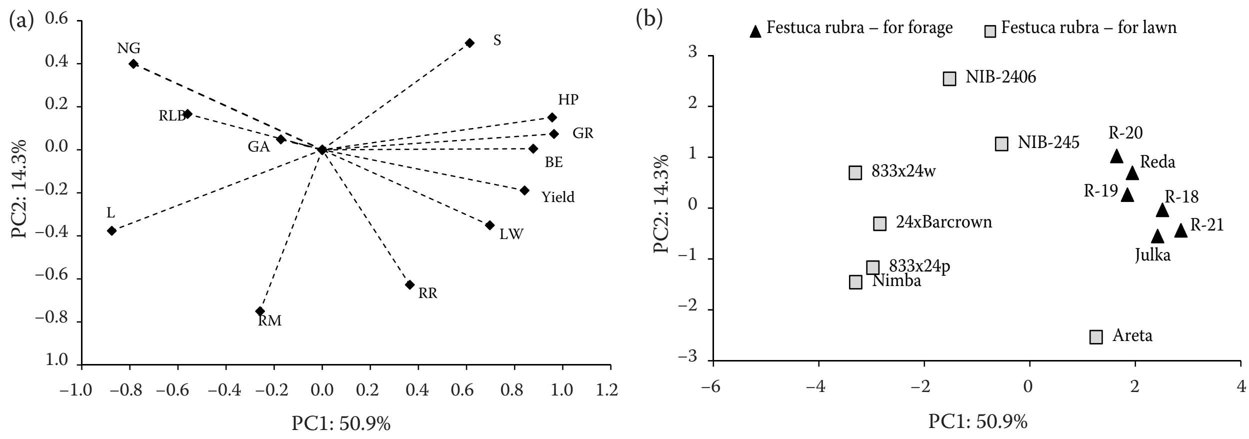

Figure 1. Results of principal component analysis (PCA) presenting relationships between the traits (a) and multivariate differences between *Festuca rubra* varieties (b)

LW – leaf width; GA – general aspect of plants; S – sodding plant cover; GR – growth rate of plants; BE – beginning of earing; L – lodging of plants; NG – number of generative shoots; HP – height of plants; RM – resistance for mildew; RR – resistance for rust; RLB – resistance for leaf blight; yield – seeds yield

tion coefficient. PCA and cluster analysis were used for this purpose. In cluster analysis, the Euclidean distance was used as a measure of object similarity and the Ward method as a method of agglomeration of objects. The analysis was performed using the Statistica (Ver. 13, 2017) and Statgraphics (Ver. 4.1, 1997) programs.

For all the analysed traits with exception of leaf blight resistance, at least one statistically significant difference between the varieties was found (Table 2). The greatest differences between varieties were observed in terms of seed yield, plant lodging, number of generative shoots, leaf width and growth rate of plants.

In order to assess the relationships between the traits, PCA was performed. On the basis of PCA (Figure 1a), interesting positive relationships between seed yield and leaf width (LW), growth rate (GR), and height of plants at maturity (HP) was found. In addition, a negative correlation was found between seed yield and lodging (L). These results were confirmed by Pearson's correlation coefficients which were positive and ranged from 0.71 to 0.80 ($P \leq 0.05$) between seed yield and LW, GR, HP and negative between seed yield and L (–0.65; $P \leq 0.05$).

Based on the PCA (Figure 1) and cluster analysis (Figure 2), substantial multivariate differences have been highlighted between forage and turf varieties; in particular forage varieties were characterised by a higher seed yield.

Similar studies on the multivariate assessment of grass varieties in relation to selected traits are so far relatively rare. Studies on multivariate variability of

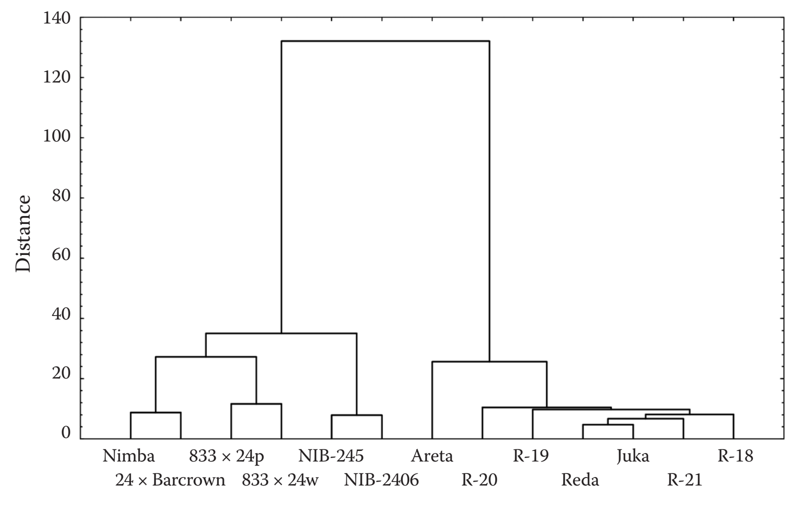

Figure. 2. Dendrogram on the basis of cluster analysis presenting multivariate similarity of examined *Festuca rubra* varieties

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F. arundinacea varieties based on molecular markers were conducted by Mian *et al*. (2005). The research was aimed at evaluating genetic similarity rather than utility. A similar research on genetic similarity, but evaluating *Poa pratensis* varieties, was conducted by Johnson *et al.* (2002). The assessment included as many as 228 meadow grass varieties from 26 countries. Furthermore, amplified fragment length polymorphism (AFLP) was used to study genetic similarity of 42 populations from eight species, among others *F. rubra*, by Majidi & Mirlohi (2010).

In the present study the cluster analysis and PCA reflected the phylogenetic relationships among species and clearly demonstrated differences in the degree of similarity among accessions. Evaluation of genetic similarity in terms of molecular markers versus the similarity of varieties in terms of traits important in the assessment of lawn grasses requires further research to confirm such relationships.

Based on the results obtained, it was found that the tested varieties were largely different in terms of seed yield and the traits strongly correlated with the seed yield i.e. LW, beginning of earing (BE), GR, and HP positively and L negatively. In particular, selection of *F. rubra* cultivars should include resistance for lodging as a very important trait and the new breeding cultivars for forage purposes should be characterized by high plants with large leaf width and early earing.

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