Principal Components & Classification Analysis – Tool for *Festuca rupicola* Biodynamic Estimation Depending on Grassland Fertilisation

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ABSTRACT

The grassland forage must be monitored related to the quantitative and qualitative parameters. *Festuca rupicola* is one of the grass desired in grassland forage. It is necessary to have accessible statistical tools to monitor the *Festuca rupicola* biodynamic. The objective of the present research was to study that multivariate analysis technique Principal Components & Classification Analysis (PC&CA) can be used as a statistical tool for the estimation of *Festuca rupicola* biodynamic dependent of the fertilisation. The experimental results for *Festuca rupicola* cutting were collected in June and August 2009 from a hill permanent grassland ecosystem, with a substances flow anthropic influenced by application of mineral and organic (sheep manure) fertilisers. The hill permanent grassland was situated in Banat, Romania, on a Calcic Luvisol. It was selected eight trials as PC&CA cases, the *Festuca rupicola* biodynamic data as supplementary variables, and as active variables the fertilisation data and ecological soil parameters. The correlation coefficients of *Festuca rupicola* biodynamic parameters (Fr1 and Fr2) were positively in mineral fertilisation case and negatively for sheep manure application. The *Festuca rupicola* biodynamic in June 2009 was high positive correlated with the *Festuca rupicola* biodynamic in August 2009 (0.835). The statistical data performed in the present study have shown that the multivariate analysis technique PC&CA can be used as a statistical tool for the estimation of *Festuca rupicola* biodynamic dependent of the mineral and/or organic fertilisation of hill grassland ecosystem.

Keywords: *ecosystem, fertilisation, forage, grass, multivariate analysis.*

INTRODUCTION

The forage from permanent grassland represents also in Romania the cheapest feed (Moisuc and Dukic, 2002) relating to the cost of the productive value of animal. According with Marusca *et al.* (2010), the grassland forage can assure the feed for 60% of cattle and 80% of sheep in our country. For maximize the animal production is of foremost importance to monitor the quantitative and qualitative parameters of grassland forage. The floristic composition of grassland covering biomass is one of the determinant parameter which influence the forage quality and quantity. The grassland plants production can be influence anthropic by the

amendments and fertilisers (mineral and/or organic) application (Dragomir, 2005; Iacob *et al.*, 2000; Rotar and Carlier, 2010; Van Dijk *et al.*, 2015), because of the necessities of available inputs vs. outputs equilibrium requirements assurance also for permanent grassland ecosystem.

Festuca rupicola is a desired grass in the forage of grassland spontaneous flora. The stimulation of native perennial *Festuca rupicola* biodynamic in permanent grassland ecosystem must be an objective for farmers. To monitor the *Festuca rupicola* biodynamic it is necessary to have simple and accessible statistical tools. Multivariate analysis technique was used more and more in the last years to monitor in the

same time a large number of qualitative and quantitative parameters for plants (Abdur Rahim *et al.*, 2008; Arceusz and Wesolowski, 2015; Chun *et al.*, 2007; Gader *et al.*, 2014; Sinha and Mishra, 2013), even for grassland forage (Poetsch *et al.*, 2014; Scotton *et al.*, 2005). The present research was conducted to use the multivariate analysis technique PC&CA as a statistical tool in case of *Festuca rupicola* biodynamic estimation dependent of the fertilisation of a hill permanent grassland ecosystem.

MATERIALS AND METHODS

Festuca rupicola harvesting

The *Festuca rupicola* samples were cut in 2009 from a permanent grassland situated in a hill region of Romania, in two steps: first time in June, and the second time in August. The percent of this grass individual participation in the grassland covering biomass was determinate gravimetrically.

Soil and climatic conditions of experimental field

The hill permanent grassland, chosen as experimental field for *Festuca rupicola* biodynamic study, was situated in Caras-Severin district, near Gradinari village (45°12'N; 21°60'E), and was for the first time fertilised in 2003, mineral yearly (NPK complex, ammonium nitrate, superphosphate, and potassium salt) and organic at each two years (fermented sheep manure).

Calcic Luvisol was the experimental field soil. Humus content was estimated using Walkley – Black – Gogoasă method, and the available phosphorus and potassium (mobile form) from soil were quantified by Egner-Riehm-Domingo method: extraction with ammonium acetate-lactate solution at pH=3.7 (Stoica *et al.*, 1986). The soil hydrolysis pH (SR ISO 10390/1999) of hill permanent grassland trials in studied period varied between 5.43 – 6.00, more acidified in exclusive mineral fertilisation cases.

The climate is temperate continental with Mediterranean influences (Ianoş, 2005). The average temperature during April to June 2009 increased from 14.5°C to 19.5°C. In July 2009 the average temperature was around 22°C, and in August 22.4°C. The rainfall during the period April – June 2009 increased from 31 mm to 166 mm. In July 2009 the rainfall was around 133 mm, and in August 2009 around 55 mm. The climatic data were purchased from the Meteorological Station

Archive, Oravita, Caras-Severin district.

Experimental field design

The design for the experimental trials was the complete randomised block with 5 replications. Each trial had 25 m². *Festuca rupicola* grass was cut at 3 cm height above soil, from 1 m² surface of each experimental trials from the hill permanent grassland: unfertilised trial – **A**; organic fertilised trials: **B, C, D** with 20t/ha, 40t/ha and respectively 60 t/ha sheep manure; organic-mineral fertilised trial: **E** with 20 t/ha sheep manure + 50P₂O₅(kg/ha) + 50K₂O (kg/ha) + 50 N (kg/ha); mineral fertilised trials: **F**-100 N (kg/ha) + 50P₂O₅ (kg/ha) + 50 K₂O (kg/ha); **G**-150 N (kg/ha) + 50 P₂O₅ (kg/ha) + 50K₂O(kg/ha); **H**-(100+100) N (kg/ha) + 50P₂O₅ (kg/ha) + 50 K₂O (kg/ha).

Statistical analysis of the experimental results

The obtained results were statistically analysed using multivariate analysis technique Principal Components & Classification Analysis (PC&CA), with the help of StatSoft - STATISTICA VERSION 10. The number of selected cases were eight. The active variables depended on the fertilisers applications doses, and the humus, available phosphorus and potassium (mobile form) of the soil samples from hill permanent grassland. The supplementary variables were the two samples sets of *Festuca rupicola* individual participation in grassland biomass (gravimetrically determinate), harvested in June and August 2009. The results were performed via the correlation matrix.

RESULTS AND DISCUSSION

The *Festuca rupicola* biodynamic in the hill permanent grassland ecosystem, influenced anthropic by mineral and/or organic (sheep manure) fertilisation, was studied for two different periods in 2009.

For the first harvesting period (June), the obtained results for *Festuca rupicola* gravimetric percent of grassland covering biomass was: **A**-42%, **B**-28%, **C**-22%, **D**-16%, **E**-52%, **F**-51%, **G**-46% and **H**-43%. In August 2009 the gravimetric percent of grassland covering biomass by *Festuca rupicola* was: **A**-22%, **B**-25%, **C**-15%, **D**-22%, **E**-36%, **F**-40%, **G**-34% and **H**-31%. Both sets of plant cutting results were used as supplementary variables for study the *Festuca rupicola* biodynamic depending on fertilisation by PC&CA.

The active variables of multivariate analysis technique PC&CA had the role to characterise the trials ecologic conditions of grassland ecosystem depending on fertilisation doses, mineral and/or organic (sheep manure).

The humus content (0–10 cm deep) of the hill grassland trials for unfertilised case **A** was 6.18%.

For organic fertilised trials the humus content increased with the increasing of sheep manure doses: **B**-6.44%, **C**-7.62% and **D**-9.04%. The organic-mineral fertilised trial (**E**) soil had 9.03% humus, while the mineral fertilised trials had 7.28% (**F**), 6.19% (**G**), respectively 8.05% (**H**).

Another active variable used to compute the PC&CA for *Festuca rupicola* biodynamic depending on fertilisation was the available phosphorus content (0–10cm deep), mobile form, for the soil of each 8 selected experimental grassland trials: **A**-43.88 ppm, **B**-47.65 ppm, **C**-53.93 ppm, **D**-71.53 ppm, **E**-69.70 ppm, **F**-54.78 ppm, **G**-50.55 ppm and **H**-52.70 ppm. The available potassium content (0–10 cm deep), mobile form, for the soil of each 8 selected grassland trials, was:

A-229 ppm, **B**-233 ppm, **C**-230 ppm, **D**-236 ppm, **E**-251 ppm, **F**-238 ppm, **G**-224 ppm and **H**-232 ppm.

The multivariate analysis technique PC&CA was used to analyse the *Festuca rupicola* biodynamic depending on grassland fertilisation and 6 principal components were obtained, describing a quality of representation of 100%. The Eigenvalues of the correlation matrix are presented in Fig. 1.

The first principal component (PC1) had the Eigenvalue 3.319 and explained 47.42% of total variance.

The second principal component (PC2) had the Eigenvalue 2.930 and explained 41.86% of total variance. It is obviously that PC1 and PC2 explain more than 89% of total variance. The third and the fourth principal components had the Eigenvalues 0.577, respectively 0.132, and described only 8.24%, respectively 1.89% of total variance.

The correlations of principal components PC1 and PC2 vs. variables (factor loadings) of PC&CA

Fig. 1. The Eigenvalues of the correlation matrix

Tab. 1. The correlations of PC1 and PC2 vs. variables (factor loadings) of PC&CA

Variables	Principal component 1	Principal component 2
Manure (t/ha)	0.872	-0.329
N (kg/ha)	-0.902	-0.164
P (kg/ha)	-0.873	-0.474
K (kg/ha)	-0.873	-0.474
Humus (%)	0.300	-0.910
P mobile form (ppm)	0.342	-0.909
K mobile form (ppm)	0.125	-0.832
*Fr1 (%)	-0.835	-0.175
*Fr2 (%)	-0.771	-0.434

Note: Fr1 – *Festuca rupicola* biodynamic in June 2009; Fr2 – *Festuca rupicola* biodynamic in August 2009.

are presented in Tab. 1.

First cases group of multivariate analysis technique PC&CA contained the unfertilised trial **A** and the trials fertilised exclusively with sheep manure **B** (20 t/ha) and **C** (40t/ha). The second cases group included the exclusively organic fertilised trial **D**, with the highest doses of sheep manure (60 t/ha).

The third cases group classified the organic-mineral fertilised trial **E**, with the minimum sheep

manure (20 t/ha), 50 kg/ha P_2O_5 , 50 kg/ha K_2O and the minimum mineral nitrogen doses (50 kg/ha).

Last cases group, the fourth, included only exclusive mineral fertilised trials **F**, **G** and **H**, with a constant dose of 50 kg/ha P_2O_5 , respectively K_2O , and different mineral nitrogen doses: 100, 150, (100+100) kg/ha.

The PC1 of multivariate analysis technique PC&CA for *Festuca rupicola* biodynamic depending

Fig. 2. Projection of the 8 cases of hill permanent grassland fertilisation on PC1xPC2 plane

Tab. 2. The correlation coefficients between the active and supplementary variables of PC&CA

Variables	Manure (t/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Humus (%)	P mobile form (ppm)	K mobile form (ppm)	*Fr1 (%)
*Fr1 (%)	-0.840	0.588	0.821	0.821	-0.176	-0.168	0.273	-
*Fr2 (%)	-0.597	0.648	0.899	0.899	0.053	0.143	0.399	0.835

Note: where Fr1 – *Festuca rupicola* biodynamic in June 2009; Fr2 – *Festuca rupicola* biodynamic in August 2009.

on fertilisation was generally characterised by the fertilisers influence on hill permanent grassland ecosystem. The organic fertilisation with sheep manure had high positive contribution in PC1 case, while mineral fertilisation with NPK complex, ammonium nitrate, superphosphate, and potassium salt had a high negative contribution. The ecological soil parameters had high negative contribution to characterise the PC2 of PC&CA.

The projection of the selected 8 cases of hill permanent grassland fertilised trials on the PC1xPC2 plane is presented in Fig. 2.

In the experimental field conditions, characterised by the fertilisation and analysed ecological parameters of grassland soil as active variables for PC1 and PC2, was studied the *Festuca rupicola* biodynamic in June and August 2009. The projection of the supplementary and active variables on the PC1xPC2 plane is shown in Fig. 3.

The supplementary variable Fr1 indicated that *Festuca rupicola* biodynamic in June 2009 was influenced positively by mineral fertilisation and negatively by sheep manure application on hill permanent grassland ecosystem.

Fig. 3. Projection of the supplementary and active variables on the PC1xPC2 plane

The same situation was for Fr2 supplementary variable, which described the *Festuca rupicola* biodynamic in August 2009.

These observations can be analysed also using the correlation coefficients between the active and the supplementary variables of PC&CA presented in Tab. 2.

The correlation coefficients of *Festuca rupicola* biodynamic in June 2009 parameter vs *Festuca rupicola* biodynamic in August 2009 was high positively (0.835). For both studied periods (June and August 2009), the *Festuca rupicola* biodynamic was stimulated in the hill permanent grassland trials when mineral fertilisers, including mineral nitrogen, were applied, clearly shown by PC&CA. Fermented sheep manure applied since 2003, at each two years, on hill permanent grassland, reduced generally the *Festuca rupicola* participation on biomass covering in soil and climate conditions of Romanian Banat of 2009.

CONCLUSION

The statistical results obtained in the present research indicate that it is possible to use the multivariate analysis technique Principal Components & Classification Analysis as a statistical tool for the estimation of *Festuca rupicola* biodynamic depending on the mineral and/or organic fertilisation. The sheep manure used as organic input in hill permanent grassland ecosystem influenced negatively the biodynamic of *Festuca rupicola* grass, while mineral fertilisers, including mineral nitrogen, had a positive impact in both studied periods: June and August 2009.

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