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Evolution of the Botanical Composition and Forage Yield of several Perennial Fodder Legume and Grass Mixtures in the Year of Establishment

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Abstract

The research results regarding the selection of some mixtures of perennial fodder grasses and legumes suitable for the establishment of temporary pastures in Cojocna, Transylvania region, Romania, are presented in this paper. The evolution of both the botanical composition and dry matter (DM) yield on 2 cuttings, after the sowing of mixtures were measured in order to establish the best mixtures. Increases of the legume ratios in the botanical composition of swards on both first and second cutting were recorded in the mixtures where their ratios at sowing were less than 40%. Grasses, in comparison with legumes, recorded lower ratios in the structure of swards than those used at sowing, both on the first and the second cutting. Weeds had ratios of 31-75% in the botanical composition of all variants on the first cutting, while on the second cutting their ratios decreased to less than 25% in the majority of variants, except in the pure alfalfa *(Medicago sativa* L.*)* crop. The higher fodder yield was obtained on each cutting for the mixture of 6 species, including 3 legumes and 3 grasses.

Keywords: complex mixtures, botanical composition, forage yield

Introduction

The supply of fresh matter (FM) forage as periodically as possible represents one of the main objectives of cattle breeders in order to obtain constant milk productions. The health of animals, the quantity and quality of milk production, as well as the better emphasis on production potential of breeds highly depend on the quality of forage. It is known that mixtures of perennial grasses and legumes produce nutritionally balanced forage (Razec, 1994), while providing a part of the protein, carbohydrate and mineral requirements. This forage can be consumed in abundance without the risk of flatulence. The choice of mixtures of perennial grasses and legumes, unlike pure crops of perennial grasses and legumes for the establishment of temporary pastures, provides the pre-requisites of sustainable forage production (Fornara and Tilman, 2008; Helgadóttir *et al.,* 2008). Arguments in favour of such a choice are the high and constant yields (Briske, 2007; Connolly *et al.,* 2009; Frankow-Lindberg *et al.,* 2009), the agrotechnical advantages (Mommer *et al.,* 2010; Van Eekeren *et al.,* 2010), the positive impact on agroecosystems (Carlsson and Huss-Danell, 2003; De Vliegher and Carlier 2009; Peeters, 2009) and the economic efficiency (Dragomir *et al.,* 2002; Dragomir *et al.,* 2009; Peyraud *et al.,* 2009). All these advantages of mixtures are determined by some biological characteristics, such as rhythm of development and ability of competition (Grieu *et al.,* 2001; Lazzarotto *et al.,* 2009; Vintu *et al.,* 2010), morphological characteristics (Kulakovskaya *et al.,* 2002; Wachendorf *et al.,* 2001) and physiological traits (Hopkins, 2003; Jumpponen *et al.,* 2005) of plant species therein. The necessity to promote new information for farmers regarding both the mixtures of perennial grasses and legumes and the traits of species and cultivars which compose them results from the lack of information of the majority of farmers concerning the new fodder plant cultivars on the Romanian market, as well as the impact of climatic changes on forage production (Weindorf *et al.,* 2009). In the Cluj county the necessity of pasture management that is supported by new results of research, is important, as out of the total agricultural area of 427,273 ha, pastures and meadows represent 56% while arable land represents 43% (www.dadrcj.ro). Another argument regarding the importance of providing information about pasture management and forage production also results from the data provided by the Sanitary Veterinary and Food Safety Department Cluj (www.ansvsa.ro). These data show that in the year 2009, in Cluj county, the professional exploitations specialized in cattle breeding were about 38, while the non-professional exploitations specialized in bull breeding were about 20779.

Materials and methods

The experiment was set up at the beginning of March 2010 in the perimeter of the Didactical Station Cojocna of the University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca, on a luvic phaeozem soil.

The results of soil analysis (Tab. 1) revealed a pH-value of 6.96, which indicates a neutral reaction (6.81-7.20, by Rusu *et al.,* 2005). The total nitrogen content of the soil (0.33%) indicated a good supply in all experimental plots (0.221-0.35, by Rusu *et al.,* 2005). The results of soil analysis also indicated a very good P (139 ppm) supply (values over 72, by Rusu *et al.,* 2005) while for K (171 ppm) there was also a good supply (132.1-200, by Rusu *et al.,* 2005) in all experimental plots.

Tab. 1. The average values of some agrochemical soil parameters in the experimental plots (0-10 cm depth)

Depth (cm)	pH (H_2O)	Total N %	P ppm	K ppm
0-10	6.96	0.33	139	171

Geographically, the experimental field is located in the Transylvanian Plain and from a stationary point of view it has a northern orientation, at an altitude of 353.9 m.a.s.l., with 46°26′22.6″N and 23°32′19.7″E coordinates. The experimental field belongs to zone 5 out of the 10 in the Cluj county area considering the climatic conditions and soil types, according to the Agricultural Department for Rural Development Cluj (www.dadrcj.ro). The experiment was set according to the randomized blocks method with 9 variants (M1-M9), represented by a pure alfalfa crop and 8 complex mixtures, in three replications. The experimental plot area was 27 m^2. The crops/mixtures included in the experimental variants are presented in Tab. 2.

Tab. 2. Experimental variants

Variant	Species
M1-control	*Medicago sativa* L.
M2	*Medicago sativa* L., *Trifolium alexandrinum* L., *Dactylis glomerata* L., *Lolium x hybridum* Hausskn.
M3	*Lotus corniculatus* L., *Onobrychis viciifolia* Scop., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Bromus inermis* Leyss.
M4	*Medicago sativa* L., *Dactylis glomerata* L., *Festuca arundinacea* Schreb., *Lolium perenne* L.
M5	*Trifolium pratense* L., *Dactylis glomerata* L., *Festulolium* Asch. & Graebn., *Phleum pratense* L., *Lolium perenne* L.
M6	*Lotus corniculatus* L., *Phleum pratense* L., *Dactylis glomerata* L., *Festuca arundinacea* Schreb., *Festuca pratensis* Huds.
M7	*Trifolium pratense* L., *Lotus corniculatus* L., *Trifolium alexandrinum* L., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Lolium x hybridum* Hausskn.
M8	*Trifolium pratense* L., *Trifolium repens* L., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Phleum pratense* L., *Lolium x hybridum* Hausskn., *Lolium perenne* L.
M9	*Medicago sativa* L., *Trifolium repens* L., *Bromus inermis* Leyss., *Festuca arundinacea* Schreb., *Lolium* x *hybridum* Hausskn

Two cuttings were organized. Each cutting was initiated in the heading-beginning of flowering of legumes. The yield and botanical composition of each variant was determined gravimetrically. The green mass from each experimental plot was harvested and weighed and afterwards, samples of 200 g of fresh matter were collected in order to determine the dry matter yield, as well as samples of 500 g fresh matter in order to establish the botanical composition of the sward for each variant. Determination of dry matter was performed by drying of samples in an oven at 60°C for 48 hours. The botanical composition was determined through separation of each sample into three groups of plants (grasses, legumes and others), each group being then weighed.

The obtained results concerning the dry matter yield were statistically analyzed by the ANOVA and Duncan test, taking into consideration the M1 variant (pure alfalfa crop) as control. To assess the relationship between the three economic groups of plants (grasses, legumes and weeds) and dry matter yields obtained in the 9 variants, for both first and second cutting, the coefficients of correlation were calculated.

Results and discussion

The ratios of grasses in the seed mixtures at planting varied between 40% and 85%, while the ratios of legumes varied between 15% and 60% (Tab. 3). The analysis of the botanical composition on the first cutting in the first year of vegetation indicated low ratios of grasses (between 5% and 15%) in the swards of all mixtures, while the ratios of legumes were higher than those of grasses, varying between 20% and 64% (Tab. 3).

The mentioned values in Tab. 3 indicate a slow installation rhythm of grasses in comparison with legumes. The low ratio of grasses in the sward favoured the installation of weeds. Weeds contributed in high ratios (between 31% and 75%) in the swards of all mixtures. The mixtures M6, M3 and M5, each one composed of 5 species recorded the highest weed development (75%, 55% and 50%) on the first cutting. The high development rates of weeds are related to the moderate development rhythm and the very poor ability of legumes to compete in the first year of vegetation, namely *O. viciifolia* and *L. corniculatus* in mixtures M3 and M6, and *T. pratense* in mixture M5. The poor competition ability of *T. pratense* in mixed swards was also noticed by Frankow-Lindberg *et al.* (2009).

The smallest ratio of weeds (31%) was recorded in mixture M7 composed of 6 species, among which 3 legumes (*T. pratense, L. corniculatus, T. alexandrinum*), with a contribution of 64%, and 3 grasses (*D. glomerata, F. pratensis, L. hybridum*), with a contribution of 5%. An important role in the competition of cultivated plants with weeds was noticed with *T. alexandrinum* and *T. pratense* species. Both species have a short life span and a rapid rhythm of development (Dragomir, 2005; Varga *et al.,* 1998). These

Tab. 3. Botanical composition on the first cutting (% from FM weight of sample)

Mixture	Grasses (% from the planting rate)	Grasses (% from the FM weight of sample)	Legumes (% from the planting rate)	Legumes (% from the FM weight of sample)	Weeds (% from the FM weight of sample)
M1	-	3	100	60	37
M2	40	9	60	55	36
M3	53	12	47	33	55
M4	70	5	30	58	37
M5	85	10	15	40	50
M6	85	5	15	20	75
M7	70	5	30	64	31
M8	78	9	22	56	35
M9	76	15	24	43	42

characteristics determine, especially with *T. alexandrinum*, a massive development immediately after plant emergence, with an advantage in the competition for light with the other species. This advantage is related to its architecture, which is similar with that of alfalfa (Schitea and Varga, 2007). A good example for the above mentioned phenomenon also occurred in the M2 mixture (*M. sativa, T. alexandrinum, D. glomerata, L. hybridum),* which included both *T. alexandrinum* and alfalfa. Schitea and Varga (2007) have also remarked the competitiveness of *T. alexandrinum* in the mixtures with alfalfa, *L. hybridum* and *D. glomerata*.

Considering the obtained yields on the first cutting (Tab. 4), mixture M7 recorded the highest yield increase (2.38 $t\cdot ha^{-1}$ DM) in comparison with the control. In the case of this mixture, the considerable contribution of legumes in the sward was reflected in the high forage production (7.70 $t\cdot ha^{-1}$ DM).

Yield increases in comparison with the control were also obtained for mixtures M2 and M8 (0.04 $t\cdot ha^{-1}$ DM and 0.19 $t\cdot ha^{-1}$ DM), but without any statistical significance.

Tab. 4. The influence of mixtures of perennial fodder species on the DM yield ($t\cdot ha^{-1}$) on the first cutting

Mixture	DM yield ($t\cdot ha^{-1}$)	(%)	Difference ($t\cdot ha^{-1}$)	Significance of difference
M1	5.32	100.0	0.00	control
M2	5.36	100.8	0.04	-
M3	4.80	90.3	-0.52	-
M4	5.18	97.4	-0.14	-
M5	4.78	89.9	-0.54	-
M6	4.01	75.5	-1.30	0
M7	7.70	144.8	2.38	***
M8	5.51	103.6	0.19	-
M9	5.13	96.6	-0.18	-
LSD 5%			0.99	
LSD 1%			1.37	
LSD 0.1%			1.88	

Note: *, 0 Symbols for significant differences (positive, respectively negative) at P<0.05, 0.01 and 0.001 according to ANOVA

The smallest yield was recorded for mixture M6 with the highest ratio of weeds (75%). The yield obtained with this mixture was lower than that obtained with the pure alfalfa crop and the difference (1.30 $t\cdot ha^{-1}$ DM) was significant. The yields obtained in case of the other mixtures (M3, M4, M5, M9) were also lower than that obtained for pure alfalfa crop but the differences were not significant.

In order to evaluate if there are differences between mixtures with close levels of obtained yields, the data were statistically approached by using the Duncan test (Tab. 5). The results indicate that there are no significant differences between the pure crop of alfalfa and 6 of the mixtures, even if certain of these data show higher (M2 and M8) or lower (M3, M4, M5, M9) yields (Tab. 5). Insignificant yield differences were also found among mixtures with over 50% weeds in the swards (M6, M3 and M5).

The estimation of the legumes contribution in the dry matter yield in legume-grass mixtures has a great importance for the management of legume-based pastures (Himstedt *et al.,* 2010). The positive distinct significant correlation coefficient (r = 0.752**) between the ratio of legumes in the sward and dry matter yield on the first cutting (Tab. 6) indicates a strong dependence between these two characters, as the higher the ratio of legumes in the sward, the higher the obtained yield. The ratio of legumes

Tab. 5. The significance of differences between DM yields ($t\cdot ha^{-1}$) as influenced by mixtures on the first cutting

Variant/mixture	DM yield ($t\cdot ha^{-1}$)	TSD p=0.05
M6	4.01 a	
M5	4.78 ab	0.99
M3	4.80 ab	1.04
M9	5.13 b	1.07
M4	5.18 b	1.09
M1	5.32 b	1.11
M2	5.36 b	1.12
M8	5.51 b	1.13
M7	7.70 c	1.13

Note: values followed by the same letters not significantly differ at P≤0.05, according to Duncan test

Tab. 6. Correlation coefficients r between dry matter yield and botanical composition of sward on the first cutting

Correlated parameters	Legumes	Grasses	Weeds
Dry matter yield	0.752**	-0.224	-0.731*
Legumes		-0.326	-0.963***
Grasses			0.062
r 5% = 0.602; r 1% = 0.735; r 0.1% = 0.847			

Note: * means correlation significant at P≤0.05, ** means correlation significant at P≤0.01, *** means correlation significant at P≤0.001

influenced negatively but insignificantly the ratio of grasses (r = -0.326). The ratio of grasses in the sward negatively correlates with dry matter yield but without a significant influence. The negative significant correlation coefficient between the ratio of weeds in the sward and dry matter yield on the first cutting indicates the negative impact of weeds on the forage yields of all tested variants. The negative and very significant correlation (r = -0.963***) between the ratio of weeds and the ratio of legumes shows the importance of legumes in the interspecific competition.

On the second cutting, grasses presented higher ratios in the structure of swards (11-50%) in comparison with those recorded on the first cutting (5-15%) but even so, their ratios remained lower than those established at sowing (Tab. 7).

The ratios of legumes in the swards of most variants on the second cutting were higher than the ratios initially established in the composition of mixtures (Tab. 7). An exception was recorded for mixture M3. The legumes *L. corniculatus* and *O. viciifolia* present a moderate development rhythm and a very low capacity of competition in the first year of vegetation. In addition, the grasses in this mixture show a moderate development rhythm (*D. glomerata* and *F. pratensis*) or slow development rhythm (*B. inermis*), poor (*B. inermis*), medium (*F. pratensis*) and high (*D. glomerata*) ability of competition. On the second cutting, legumes recorded decreases of their ratios only in mixtures 1, 3 and 4 unlike their ratio on the first cutting. In mixtures 1 and 4 the decreases of legume ratios in the botanical composition of swards were about 18%, respectively 25%. High ratios of legumes, over 70%, were observed in the swards of mixtures M7 (88%), M2 (76%) and M8 (75%).

The ratios of weeds decreased in the botanical composition of swards of all complex mixtures on the second cutting, results that are in agreement with those reported by other researchers (De Vliegher and Carlier, 2008). Out of all studied mixtures, the lowest ratio of weeds (1%) was recorded in M2 and M7, composed of 4 respectively 6 plant species. It should be noted that the two mixtures present 4 common species (*M. sativa, T. alexandrinum, L. hybridum* and *D. glomerata*). Among these species *M. sativa*, *T. alexandrinum* and *L. hybridum* present a rapid rhythm of development and *D. glomerata* has a high ability of competition in the first year of vegetation. An increase of the weed ratio was recorded only for the pure alfalfa crop where it reached 58%.

On the second cutting, dry matter yields obtained for all mixtures were higher than that obtained for alfalfa but, at the same time, the yields were lower than those recorded in the first cycle of cutting for 5 mixtures (Tab. 8). Exceptions were noted for variants 2 and 8, whose yields remained relatively constant (about 5 t·ha^{-1} DM). Another exception was recorded for variant 5 with a small yield increase (0.39 t·ha^{-1} DM). The highest dry matter yield was recorded for mixture 7, as in the first cutting. The yield increase in comparison with the control was about 3.62 t·ha^{-1} DM. Yield increases around this were obtained with mixture 5 (3.33 t·ha^{-1} DM), mixture 2 (3.53 t·ha^{-1} DM) and mixture 8 (3.53 t·ha^{-1} DM). All the yield increases were statistically significant.

The data were statistically processed by using the Duncan test (Tab. 9). It can be concluded that among mixtures 7, 2, 8 and 5 the differences were not significant.

The positive highly significant correlation coefficient between the ratio of legumes and dry matter yield on the second cutting (r = 0.865***), as on the first cutting, indicates the importance of legumes for the forage production of all variants (Tab. 10). In the interspecific competition

Tab. 7. Botanical composition on the second cutting (% from FM weight of sample)

Mixture	Grasses (% from the planting rate)	Grasses (% from the FM weight of sample)	Legumes (% from the planting rate)	Legumes (% from the FM weight of sample)	Weeds (% from the FM weight of sample)
M1	-	0	100	42	58
M2	40	23	60	76	1
M3	53	47	47	30	23
M4	70	48	30	33	19
M5	85	35	15	54	11
M6	85	47	15	29	24
M7	70	11	30	88	1
M8	78	18	22	75	7
M9	76	50	24	43	7

Tab. 8. The influence of mixtures of perennial fodder species on the DM yield ($t \cdot ha^{-1}$) on the second cutting

Mixture	DM yield ($t \cdot ha^{-1}$)	(%)	Difference ($t \cdot ha^{-1}$)	Significance of difference
M1	1.84	100.0	0.00	control
M2	5.37	291.8	3.53	***
M3	2.83	153.6	0.99	***
M4	2.52	137.1	0.68	*
M5	5.17	281.1	3.33	***
M6	3.07	166.8	1.23	***
M7	5.46	296.9	3.62	***
M8	5.37	291.8	3.53	***
M9	3.42	186.1	1.58	***
LSD 5%			0.51	
LSD 1%			0.71	
LSD 0.1%			0.97	

Note: *, 0 Symbols for significant differences (positive, respectively negative) at P<0.05, 0.01 and 0.001 according to ANOVA

Tab. 9. The significance of differences between DM yields ($t \cdot ha^{-1}$) as influenced by mixtures on the second cutting

Variant/mixture	DM yield ($t \cdot ha^{-1}$)	TSD p=0.05
M1	1.84 a	
M4	2.52 b	0.51
M3	2.83 bc	0.54
M6	3.07 cd	0.55
M9	3.42 d	0.57
M5	5.17 e	0.57
M8	5.37 e	0.58
M2	5.37 e	0.58
M7	5.46 e	0.59

Note: values followed by the same letters not significantly differ at P≤0.05, according to the Duncan test

Tab. 10. Correlation coefficients r between dry matter yield and botanical composition of sward on the second cutting

Correlated parameters	Legumes	Grasses	Weeds
Dry matter yield	0.865***	-0.262	-0.815**
Legumes		-0.640*	-0.588
Grasses			-0.245
r 5% = 0.602; r 1% = 0.735; r 0.1% = 0.847			

Note: * means correlation significant at P≤0.05, ** means correlation significant at P≤0.01, *** means correlation significant at P≤0.001

between legumes and grasses, a high ratio of grasses in the botanical composition of variants correlates with a significant decrease of legumes ratio (r = -0.640*). The negative distinct significant coefficient of correlation (-0.815**) between the presence of weeds in the botanical composition of swards of all variants and dry matter yields indicates that the relationship between the high ratio of weeds and the low level of yield is stronger on the second cutting than on the first.

Conclusions

The low development rhythm of the majority of grasses in the first year of vegetation and on the first cutting determined the existence of numerous ecological niches which permitted the installation of weeds. The ratios of grasses in the swards, both on the first and second cutting were lower than the ratios established at sowing. Regarding legumes, both on the first and second cutting, increases of their ratios in the botanical composition of swards were recorded in the mixtures where their ratios at sowing were less than 40%. On the first cutting, weeds exhibited ratios of 31-75% in the botanical composition of variants, while on the second cutting their ratios decreased below 25% in all mixtures, except in the pure alfalfa crop. The highest forage yield was obtained on each cutting in case of the mixture composed of 6 species, among which 3 legumes (*T. pratense, L. corniculatus, T. alexandrinum*) and 3 grasses (*D. glomerata, F. pratensis, L. hybridum*). Mixtures M2 and M8 composed of 4 respectively 7 species should also be mentioned because they did not get significant differences in yield between the two cuttings, moreover they had a relatively constant level of yield, around 5 $t \cdot ha^{-1}$ DM.

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References

Briske, D. D. (2007). Plant Interactions, p. 102-122. In: Barnes R. F., C. J. Nelson, K. J. Moore and M. Collins (Eds.). Forages: The science of grassland agriculture. 6th Edition. Blackwell Publishing.

Carlsson, G. and K. Huss-Danell (2003). Nitrogen fixation in perennial forage legumes in the field. Plant and Soil 253(2):353-372.

Connolly, J., J. A. Finn, A. D. Black, L. Kirwan, C. Brophy and A. Lűscher (2009). Effects of multi-species swards on dry matter production and the incidence of unsown species at three Irish sites. Ir. J. Agr. Food Res. 48(2):243-260.

De Vliegher, A. and L. Carlier (2008). Potential of fodder legumes under intensive farming conditions in Flanders. Biodiversity and animal feed-future challenges for grassland production. Proceedings of the 22nd General Meeting of the

European Grassland Federation. Uppsala, Sweden 13:236-238.

De Vliegher, A. and L. Carlier (2009). The value for agricultural use of grass seed mixtures of species and varieties in comparison with single varieties. Bulletin UASVM. Agriculture 66(1):231-236.

Dragomir, N., C. Dragomir, C. Cristea and D. Rechitean (2002). Research regarding the atmospheric nitrogen fixation by mixture of perennial grasses and legumes. Bulletin of UASVM. Animal Husbandry and Biotechnology 57:322-325.

Dragomir, N. (2005). Pastures and fooder plants-technologies of cultivation. Ed. Eurobit. Timisoara (in Romanian).

Dragomir, N., I. Pet, C. Dragomir, E. Pet, C. Cristea, D. Rechitean, S. Toth and I. Fratila, (2009). Multifunctionality and sustainability of the utilization of permanent pastures in Romania, under conditions of alternative utilization. Proceedings of the 15th Grassland Federation Symposium. Brno, Czech Republic 14:87-90.

Fornara, D. A. and D. Tilman (2008). Plant functional composition influences rates of soil carbon and nitrogen accumulation. Journal of Ecology 96(2):314-322.

Frankow-Lindberg, B. E., M. Halling, M. Hoglind and J. Forkman (2009). Yield and stability of yield of single- and multi-clover grass-clover swards in two contrasting temperate environments. Grass and Forage Science 64(3):236-245.

Grieu, P., D. W. Lucero, R. Ardiani and J. R. Ehleringer (2001). The mean depth of soil water uptake by two temperate grassland species over time subjected to mild soil water deficit and competitive association. Plant and Soil 230(2):197-209.

Helgadóttir, A., J. Connolly, R. Collins, M. Fotergill, M. Kreuzer, A. Lűscher, C. Porqueddu, M. T. Sebastia, M. Wachendorf, C. Brophy, A. J. Finn, L. Kirwan and D. Nyfeler (2008). Biodiversity and animal feed - future challenges for grassland production. Proceedings of the 22nd General Meeting of the European Grassland Federation. Uppsala, Sweden 13:39-49.

Himstedt, M., T. Fricke and M. Wachendorf (2010). The relationship between coverage and dry matter contribution of forage legumes in binary legume-grass mixtures. Crop Sci., 50(5):2186-2193.

Hopkins, W. G. (2003). Physiologie végétale. Ed. De Boeck Université. Bruxelles. Imprimé en Espagne.

Jumpponen, A., C. P. H. Mulder, K. Huss-Danell and P. Hogberg (2005). Winners and losers in herbaceous plant communities: insights from foliar carbon isotope composition in monocultures and mixtures. Journal of Ecology 93(6):1136-1147.

Kulakovskaya, T., A. Meerovski and N. Vachonin (2002). Vertical distribution of stand grass and dry matter yield for grass mixtures and monoculture during the modified cutting regimens. Multifunction grasslands-Quality Forages, Animal Products and Landscape, Proc. of the 19th General Meeting of the European Grassland Federation. La Rochelle, France 7:326-327.

Lazzarotto, P., P. Calanca and J. Fuhrer (2009). Dynamics of grass-clover mixtures-An analysis of the response to management with the PROductive GRASsland Simulator (PROGRASS). Ecological Modelling 220(5):703-724.

Mommer, L., J. van Ruijven, H. de Caluwe, A. E. Smit-Tiekstra, C. A. M. Wagemaker, N. J. Ouborg, G. M. Bogemann, G. M. van der Weerden, F. Berendse and H. de Kroon (2010). Unveiling below-ground species abundance in a biodiversity experiment: a test of vertical niche differentiation among grassland species. Journal of Ecology 98(5):1117-1127.

Peeters, A. (2009). Importance, evolution, environmental impact and future challenges of grasslands and grassland-based systems in Europe. Grassland Science 55:113-125.

Peyraud, J. L., A. Le Gall and A. Lűscher (2009). Potential food production from forage legume-based-systems in Europe: an overview. Ir. J. Agr. Food Res 48(2):115-135.

Razec, I. (1994). Researches concerning the production, quality and possibility for ensilage of some simple and complex mixtures of perennial grasses and legumes for pastures. UASVM., Cluj-Napoca, PhD. Thesis.

Rusu, M., M. Marghitas, I. Oroian, T. Mihaiescu, A. Dumitras (2005). Agrochemical handbook. Ed. Ceres, Bucuresti (in Romanian).

Schitea, M. and P. Varga (2007). Achievements in fodder plants' breeding at Fundulea. An. I.N.C.D.A. Fundulea 75:203-227 (in Romanian).

Van Eekeren, N., M. Bos, J. De Wit, H. Keidel and J. Bloem (2010). Effect of individual grass species and grass species mixtures on soil quality as related to root biomass and grass yield. Applied Soil Ecology 45(3):275-283.

Varga, P., Al. Moisuc, M. Savatti, M. Schitea, C. Olaru, N. Dragomir and M. Savatti jr. (1998). The breeding of fodder plants and the production of seeds. Editura Lumina (in Romanian).

Vintu, V., I. Talpan, A. Ionel and C. Samuil (2010). Influence of mixture and fertilization on the behaviour of some grasses and perennial legume species on temporary pasture in the Moldavian forest steppe. Romanian Journal of Grasslands and Forage Crops 1:81-91.

Wachendorf, M., R. P. Collins, A. Elgersma, M. Fothergill, B. E. Frankow-Lindberg, A. Ghesquiere, A. Guckert, M. P. Guinchard, A. Helgadottir, A. Lűscher, T. Nolan, P. Nykanen-Kurki, J. Nosberger, G. Parente, S. Puzio, I. Rhodes, C. Robin, A. Ryan, B. Staheli, S. Stoffel, F. Taube and J. Connolly (2001). Overwintering and growing season dynamics of *Trifolium repens* L. in mixture with *Lolium perenne* L. A model approach to plant-environment interactions. Annals of Botany 88(SI):683-702.

Weindorf, D., B. Hagard, T. Rusu, H. Cacovean and S. Johnson (2009). Soil temperatures of the Transylvanian Plain, Romania. Bulletin UASVM. Agriculture 66(1):237-242.

www.ansvsa.ro

www.dadrcj.ro