

UNIVERSITATEA DE ȘTIINȚE AGRICOLE ȘI MEDICINĂ VETERINARĂ DIN CLUJ-NAPOCA
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TEZĂ DE ABILITARE

Producerea sustenabilă de furaje în pajiști permanente, temporare și culturi anuale

Sustainable fodder production in permanent and temporary pastures and annual crops

Domeniul: **Agronomie**

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A. ABSTRACT

The present habilitation thesis has been written and structured following the requirements of both the current legislation and the regulations concerning the habilitation procedures and co-optation of PhD supervisors, approved by the senate of the UASMV (University of Agricultural Sciences and Veterinary Medicine) from Cluj-Napoca in 2017.

The content of the habilitation thesis has been summarized in form of an abstract written in both Romanian and English. Section I - A short introduction gives insights into the concept of multifunctional agriculture, particularly in the context of pastures and their associated ecosystem services. This concept is essential for understanding the importance and opportunity of addressing the main disciplinary and interdisciplinary research topics which lie at the core of my past and future scientific activity. Finally the results of scientific research conducted after 2003 (the year in which I obtained my **PhD in Agronomy**) are presented, followed by an overview of professional and academic achievements. Section II – This section offers insights into future professional, scientific and academic perspectives.

The introduction provides an overview of: a) the current paradigm on agricultural policies promoted by the national management plans on rural development of EU member states; this paradigm is represented by an holistic approach to multifunctional agronomy, a locally integrated model which aims to create a new bond between producers and consumers by using local resources. b) eco-system services provided by permanent pastures (provisioning services, supporting services, regulating services and cultural services) as well as of the interest which these types of services raise in European policy-makers. c) the role of the academic in integrating scientific results from economic, social and environmental study fields with the orientation and decisions of policy-makers in respect to the way agricultural lands (including pastures) are used.

The main disciplinary and interdisciplinary research topics are influenced by the concept of multifunctionality and aim at assessing ways of:

- sustainable production of fodder in permanent and temporary pastures;
- production of fodder under changing climate.

The first research topic has materialized through results obtained following scientific research conducted between 2004 and 2006 within the framework of two type AT research projects for which I have served as project coordinator. These projects were awarded through national competitions organized by CNCISIS (National University Research Council). The main results obtained during these projects will be briefly presented below.

The research conducted during the duration of the first project, “Research regarding the sustainable use of montane pastures with *Festuca rubra* from the Cindrel mountains (CNCISIS code 101, 2004 – 2005)” has been used to complete the data portfolio comprising analyses on the impact of management practices (organic fertilization, organic and mineral fertilization, number of defoliations) on the montane pastures with *Festuca rubra* from the Cindrel mountains. The way these pastures are managed could affect the amount of fodder produced, its chemical composition and its quality (which should correspond to the nutritional requirements of domestic animals). Other consequences may relate to the evolution of plant diversity within the grass layer, which may be improved by stimulating the recruitment and/or growth of fabaceous species and by improving the chemical properties of the soil and its trophicity. Based on the obtained results it can be concluded that management practices involving organic and organic and mineral fertilization combined with 1-2 defoliations have led to: I) qualitative changes in the grass layer were found in all fertilization regimes, being reflected by an increase in the recorded number of species, particularly the appearance of valuable species such as *Poa pratensis*, *Dactylis glomerata*, *Cynosurus cristatus*, *Lotus corniculatus*, but also some undesirable species like *Rhinanthus glaber* (a hemiparasite); another consequence were quantitative changes reflecting a higher frequency of already occurring species such as *Festuca rubra*, *Agrostis capillaris*, *Phleum alpinum* and *Trifolium*

pratense. II) an increase in the production in comparison to non-fertilized pastures, however significant differences were only found when comparing the complex fertilization scheme (organic and mineral) to the simple schemes (either organic or mineral). The decreasing hierarchy of the harvests was correlated to the decrease in the amount of N. III) the improvement of the fodder quality and chemical composition (particularly for the treatments which included only manure and P, K combined with two defoliations). The obtained fodder was characterized by a higher protein and mineral content and by a lower net content of cellulose.

The results obtained during this first project allowed the identification of a technical solution (22 t manure·ha⁻¹·year⁻¹ + 50P100K kg·ha⁻¹·year⁻¹ + 2 harvests), which can be recommended to the local farmers and which corresponds to the principles of sustainable development. This solution would ensure an increased harvest, while building on the energetic resources of the *F. rubra* pratoecosystem by increasing the proportion of fabaceous and thus of the possibility of symbiotic fixation of atmospheric N. This would also increase the quality and quantity of the harvest and lead to an improvement over time of the chemical properties of the soil.

The scientific results obtained during this first project have highlighted the production and habitat functions of the montane *F. rubra* pratoecosystem, as well as its capacity to ensure ecosystem services included in the categories of provisioning.

The second project belonging to the first research topic, „Research concerning carbon storage in several montane and silvosteppeic grassland ecosystems, CNCSIS code 113 (2006)“ has focused on highlighting the regulatory function of the montane *F. rubra* pratoecosystem. This ecologic function and its associated ecosystem services were thereby compared between the montane *F. rubra* pratoecosystem and a temporary pasture agro-ecosystem. Furthermore this project has represented the starting point for research on the production of fodder on arable land, a thematic component of the second research topic the production of fodder under climate change.

The idea of addressing such a research topic as carbon storage has evolved in the context of an increased interest at an international level for understanding the eco-protective function of pastures. At this point in time (2006, prior to Romania's accession to the EU) the increased interest for environmental issues was just beginning to emerge. Today the eco-protective role of pastures and the ecosystem services they provide are already well known and widely accepted. Thus, similarly to forests, pastures can store atmospheric CO₂ and limit or even halt soil erosion. These functions can be explained by the morphological, biological and physiological properties of the herbaceous species found in pastures as well as by the technological properties of pastures, in which annual perturbations of the soil through activities such as ploughing are lacking. To the aforementioned particularities of pastures, the high ecological plasticity of most herbaceous species needs to be added. This particularity permits the valorification of low value agricultural lands, such as those with low trophicity and acid pH or those situated on arid, slopes with starting or ongoing degradation which would be unfavorable to other cultures.

The actuality of the presented research topic has been also confirmed by the importance which has been attributed to pastures by the EU in the documents it has elaborated in 2009 regarding the impact of agriculture on climate change. The data presented in this document indicated that for the agricultural lands within the EU in 2007 the net CO₂ emission rate was 57 million tons. Arable lands have represented the net CO₂ emission sources, producing 70 million tons, while pastures represented the net CO₂ storage sources, capturing 13 million tons.

The results obtained through research conducted within the framework of this project have been obtained through two experimental setups established within a permanent grassland and an experiment conducted within a temporary pasture. The two experimental setups established within the permanent pastures have included:

- an experimental setup in which mowing was used to quantify level of above-ground net primary production (ANPP), expressed through the production of dry matter obtained: a) under the use of both mineral and organic fertilizers and b) following the interaction

between liming and fertilization (mineral and organic) and the contents of organic carbon in the soil.

- an experimental setup in which the efficiency of accumulation and the content of soil's organic carbon have been quantified following grazing.

The data obtained from the experiment conducted in permanent *F. rubra* pastures have shown that after 8 years of experimental treatments the harvest was increased in all trials, independently of whether a single treatment or an interaction of treatments was used. The best results were however obtained in those treatments which involved mineral fertilization and limed soil.

An increase in the above-ground primary net production does not necessarily directly correlate with an increase in the organic carbon in the soil. Thus the decreasing hierarchy of the production of dry matter changes regarding the accumulation of organic carbon in the soil between treatments with both soil improvement and fertilization with $N_{100}P_{22}K_{83}$ $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$; $P_{22}K_{83}$ $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ + overseeding with *T. repens* and treatments with a $N_{100}P_{22}K_{83}$ $\text{kg}\cdot\text{ha}^{-1}\cdot\text{an}^{-1}$ fertilization scheme. Decreasing quantities of soil organic carbon (SOC) were observed to accumulate in the soil of treatments involving N fertilization (significant increase in comparison to controls, pastures without inputs) and in those involving fertilization and overseeding.

The experiment conducted in pastures which have been sown on arable land has included two types of mixtures: a simple mixture (poaceous-fabaceous) and a complex mixture (3 species of poaceous and 3 species of fabaceous) which were sown on 3 areas formerly used to cultivate with 3 wider crop rows. The results obtained during these experiments allowed us to conclude that the humus content of the soils under sown pastures is 1,9 to 3,23 smaller than in soils of natural *F. rubra* pastures. This low humus content needs to be correlated with the following series of factors: the more intense mineralization of organic matter as a consequence of land use practices, namely ploughing; the eco-pedologic conditions characteristic for the silvosteppe (altitude, mean annual temperature); technical particularities related to the harvesting of the crops previously cultivated on those lands which were transformed into pastures (narrow crops rows vs wider crops rows) and finally the high level of fodder harvest offered by temporary pastures (above-ground primary net production – dry matter).

The second research topic has materialized through results obtained by research conducted between 2009 and 2011 in the framework of the project "Establishing an assortment of annual and perennial fodder plants under conditions characteristic for the Transylvanian Plain in order to limit the negative effects of drought on the production of feed (IDEI project, CNCISIS code ID 1488)".

Ensuring the fastest rhythm of covering the demand for fresh matter (FM), feed as well as providing good quality feed are the main goals of cattle breeders. Constant supply of high quality feed ensures that the health of the animals can be maintained and that the production potential of the breeds is maximized. It is well known that a mixture of perennial fodder grasses and legumes ensures a balanced nutritional input ensuring at the same time part of the required protein, carbohydrate and mineral intake. The choice of mixtures for the establishment of temporary pastures and including these besides the annual fodder cultures into fodder crop structures which can be recommended to farmers at a local and regional level has the aim of minimizing the negative economic and social impact of extreme weather phenomena. Such a choice represents a favorable premise for the sustainable production of fodder, as these mixtures ensure: rich and constant harvests, agro-technical advantages, a positive impact on the agro-environment, great flexibility and low vulnerability in exploitation and economic efficiency under extreme weather conditions. These advantages have to be considered particularly in comparison to annual crops.

The scientific research experiments planned in the framework of this project have been carried out at the Didactic Experimental Station at COJOCNA belonging to the UASVM Cluj-Napoca. The experiments were carried out at two locations, the COJOCNA and JUCU farms, respectively. At both locations an experiment has been set up where the following perennial grass and legume

fodder plant seed mixtures have been tested: a pure alfalfa crop, two mixtures created by the Institute of Pastures Braşov, two commercial mixtures available on the market and three mixtures created by the applicant. These mixtures were tested with three fertilization gradients (F1–0N0P₂O₅, F2–60N70P₂O₅, F3–100N70P₂O₅ kg·ha⁻¹·year⁻¹). In 2011 at the experimental field at COJOCNA an experiment has been set up using C3 and C4 type annual fodder plants (mixture with pea + oat, mixture with pea + triticale, rape, millet, sorghum x Sudan grass hybrid, sweet sorghum) exposed to the same three fertilization gradients described above. The aim of this last experiment was to test the possibility of using these assortments of fodder plants for obtaining FM under the present day climatic conditions encountered within the Transylvanian Plain. A collection of perennial poaceous and fabaceous fodder species and varieties, which have been used in the studied mixtures, have been also established at COJOCNA. The fodder species from the collection have been cultivated on the same three fertilization levels.

The research objectives have been the following: 1) creating a deep understanding of the research topic based on an interdisciplinary research approach (combining agronomy, ecology, biochemistry, physics – mass spectrometry for isotopic rapports); obtaining a high quality research and technological output; obtaining results which would have a broad impact at both the regional and the international level by assessing the response of species, varieties and hybrids from the fodder agro-ecosystems found in the Transylvanian Plain (annual crops, pastures) under the impact of climate change (increased concentration of CO₂, increasing temperatures, water scarcity); 2) developing technological solutions based on inter- and trans-disciplinary research which can generate direct benefits by limiting the economic, social and environmental costs, as well as by creating the opportunity of funding in accordance with CAP; this objective was based on research aimed to fill the knowledge gap related to the water-use efficiency of annual and perennial C₃ and C₄ type fodder plants under conditions of hydric stress (drought) and differential fertilization.

The originality of the obtained results is given by the opportunity to develop a new work paradigm for determining the species and even the varieties which should make up the perennial grass and legume mixtures designed for fodder production. This approach takes into account the fact that the isotopic carbon discrimination in plants ($\Delta^{13}\text{C}$) and the rapport between the partial CO₂ pressures in the leaves of the plants are parameters directly linked to the biomass production. Such an approach, based on the correlation between $\Delta^{13}\text{C}$ and the improvement of water use efficiency (*WUE*) can open new research avenues in plant genetics and plant breeding by using water use efficiency as a selection criterion for fodder plants in Romania.

The diversity of extreme weather conditions encountered during the time of the research (2009 – 2011) in the two previously mentioned locations and the experimental factors which have been studied have facilitated the clear assessment of differences between the studied species and crops, differences which could be successfully used in establishing various culture structures with the aim of obtaining a sustainable production of fodder: a) the following mixtures have been proven to be clearly superior in comparison to the alfalfa monoculture (A1), the old perennial grass and legume mixture (A3) formerly recommended for the silvosteppe and other mixtures: A7. *Trifolium pratense* L., *Lotus corniculatus* L., *Trifolium alexandrinum* L., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Lolium x hybridum* Hausskn. (70% graminee și 30% leguminoase); A8. *Trifolium pratense* L., *Trifolium repens* L., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Phleum pratense* L., *Lolium x hybridum* Hausskn., *Lolium perenne* L. (78% grasses și 22% legumes) – newly established mixtures; A5. *Trifolium pratense* L., *Dactylis glomerata* L., *Festulolium* Asch.&Graebn., *Phleum pratense* L., *Lolium perenne* L. (85% graminee and 15% leguminoase); - comercially available mixture; for JUCU the A6 mixture has also proven successful, A6. *Lotus corniculatus* L., *Phleum pratense* L., *Dactylis glomerata* L., *Festuca arundinacea* Schreb., *Festuca pratensis* Huds. - 85% grasses and 15% legumes. b). the A7 and A8 mixtures were shown to be superior to all other mixtures based on the results obtained from establishing the isotopic $\Delta^{13}\text{C}$ discrimination and the water use efficiency parameter (*WUE*) of all plant species included in these mixtures during 2010 and 2011; c). the higher quality of

the provided fodder clearly separates the A7 and A8 mixtures from all other tested mixtures and from the alfalfa monoculture.

The experimental results obtained from investigating the potential of annual fodder crops as sources of FM under the ecological conditions characteristic for COJOCNA have allowed us to draw the following conclusions: the assortment of FM crops which can be included into the composition of a green fodder crops structure for fresh matter production and which would ensure a fodder with an optimal rapport between quantity and quality includes the following species and or varieties: mixture with oat+pea, mixture with pea + triticale . During the water scarcity of 2011 the cultures sorghum x Sudan grass hybrid (CI + CII) și sweet sorghum have proven to be of interest, both through the rich fodder harvest obtained under differential fertilization schemes for sweet sorghum and the succession of the production of the sorghum x Sudan grass hybrid (CI + CII).

The results presented within the present habilitation thesis are relevant for the PhD field „Agronomy”, the field for which the application for obtaining the status of PhD supervisor has been submitted. The validation of the inclusion of the research topic of the presented projects in the field of Agronomy is confirmed also by the fact that within the national competition organized by the CNCISIS the projects were appointed to 5th commission – agriculture, sub-commission 5a.

The scientific results obtained and the professional expertise gained following the comprehensive research activities conducted during my career have led on a **scientific plan** to a) the publication of numerous scientific papers and books with a disciplinary, interdisciplinary and trans-disciplinary character; b) the co-author of a new *Festuca arundinacea* variety for which a patent has been obtained; c) contributions to the training of 7 PhD students (3 of which are currently employed by the Faculty of Agronomy, USAMV Cluj-Napoca on permanent teaching positions) by ensuring their scientific formation and the consolidation of their research skills and abilities. On a **professional plan** I was able to provide expert advice both on practical matters for the management of temporary and permanent pastures of high nature value (HNV) and on theoretical matters as a trainer in agro-environment measures (PNDR 2007-2013) and management of HNV sites for community facilitators. On a **academic plan** I have built on the results of my scientific research by acting as an editor for several handbooks, which are used by students following the study programs „Agricultural biotechnologies” and „Biotechnologies in the food industry” of the Faculty of Animal Husbandry and Biotechnology within the framework of the instructive program of the course „Obtaining and capitalization of plant production”. For the students chosen for internship positions within the study program (an internship which was focused both on laboratory and field work), I have contributed to the development of profound practical and scientific abilities. The cooperation with these students has materialized in the realization of 5 bachelor thesis, 5 contributions to the scientific student symposia held by the USAMV Cluj-Napoca and 1 dissertation thesis.

The validity of the impact of my research activity on my scientific, professional and academic achievements are verifiable as usually the before mentioned realizations were quantified during the course of projects or at the end of projects as part of the performance evaluations which determined the continuation or the finalization of the projects funding.

The scientific and didactic realizations, obtained during 20 years of activity in higher education and scientific research, are briefly presented in the present habilitation thesis. I consider that these achievements provide a clear overview of my past professional carrier and on my future development as a PhD supervisor. This new carrier step implies a complex and exciting activity which is associated with a great professional and moral responsibility, as it offers the possibility to shape the future young specialist which will carry the honorable title of **PhD in Agronomy**.