EDUCATIONAL PLAN

Festetics Doctoral School

Hungarian University of Agriculture and Life Sciences, Georgikon Campus
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Introduction of the Doctoral School and overview of its educational possibilities

According to the reorganizations performed at the fall of 2007, the Keszthely-based Georgikon Faculty of the University of Pannonia had two entities for graduate students: the Animal and Agri-Environmental (ÁADI) and the Plant Production and Horticulture (NKTDI) Doctoral Schools. In their decision - dated on December 12th 2014 and received in March of 2015 - the Hungarian Accreditation Council (MAB) recommended that the two Doctoral Schools should be merged. This was achieved as detailed below.

The merged inter-disciplinary Festetics Doctoral School (from here FDS) intends to conduct graduate training in the following three disciplines: (i) Animal Production, (ii) Horticulture and Plant Production and (iii) Environmental Sciences. Accordingly, the educational and research program of FDS consists of three broad areas of sciences and can be divided into a number of subprograms. Basic and specialized subjects do vary among the three broad areas, we will provide the list of topics separately. As the compulsory and elective nature of the subjects depends on the research project of the students, thus personal educational plans must be designed in collaboration with the PhD supervisor. Written plans must be submitted to and approved by the Council of the Doctoral School (CDS).

Students are allowed to apply for several projects that are in different disciplines. In case of such multidisciplinary projects, the disciple that takes up the majority of the work, will be indicated in the final certificate of the student.

ANIMAL PRODUCTION SCIENCES

Supervisors working on the animal production field offer a wide variety of subjects from their own area of research for prospective students. Special attention is being paid to environmentally friendly and sustainable practices in animal production and nutrition as well as those basic subjects that help to prepare the students for those courses. The development of such capabilities is becoming more and more important as most intensive animal production technologies tend to put substantial pressure on the environment. Projects related to sustainable technologies of animal production that offer increased protection for Lake Balaton are given priorities. Our DS provides unique opportunities for studies on the environmental relatedness of animal production based on grazing, a subject that is not widely studied in Hungary. Due to the vertical depth of the field, we have opened 12 research areas. The coherence between the research areas are indicated by bold.

Research Area #1: Genetic and environmental effects on animal production
Leader: Péter J. Polgár, CSc

The fact that **genetics and the environment determine the phenotype** together indicates the coherence between the various areas of FDS. The parallel analysis of the genetics of our farm

animals and that of the environment during production will allow for the estimation of breeding values that in turn will make the determination of the exact target of production. In a narrow sense, production of farm animals means the tasks of selection, whereas in wider sense it involves the processes of keeping and feeding of the animals, as well as the special technologies required to generate the final product. The application of traditional animal breeding of pure lines has undergone substantial changes due to the rapid development of genetic and genomic technologies. The modern methods of biotechnology have been incorporated into the daily routine by many farms.

Parallel analyses of natural animal husbandry, the capacity of the field, and the environmental load will yield solutions for the development of sustainable animal production. This is especially important here in the vicinity of Natural Parks and Lake Balaton, where the protection of natural soils and waters must be kept in mind. The ecological ways of animal husbandry, the production potential and capacity of grazing farm animals, such as cattles, horses and sheeps, are among our most important research projects.

Coordination of the selection programs of farm animal lines specialized for meat and milk production, requires continuous development involving frequent grading of the phenotype appropriate for the requirements of lineage and production as well. Analysis of the effects of abiotic and biotic environment on the animal production also points to a number of related areas. The ethological aspects of animal behavior in open and closed systems are essential aspects of animal husbandry. The well-being of the animals must be provided through the incorporation of requirements of animal welfare into the technological developments that in turn results in increased safety of food production and increased quality of products, offering another set of potentially valuable research projects. **Neither and experiment, nor an efficient production technology can be designed without the analyses of the environmental needs of various age groups and their incorporation into the production technologies.**

For animals kept and grown with 'closed technologies' one of the most important environmental factors if their feed. Regulation of the elements of technological systems (e.g. breeding, placement and nutrition) and the planning parameters of the artificial environment will determine the production potential of the individuals and the whole stock. The metabolic background of production processes and their physiological parameters are being analyzed in several projects.

The efficient management of resources will further improve with the incorporation of digitalization and the introduction of technologies involved in 'high precision animal production'. This will likely improve the data safety and informative capabilities of databases of production facilities.

Research Area #2: Nutrition of farm animals
Leader: Károly Dublecz, PhD

There are a number of challenges facing the nutrition of farm animals recently, like the effects of climatic change and its effect on the production and quality of feedstuffs, the increasing production volume of biofuels, the constraints due to the reduction of greenhouse gases, the need to improved food quality and increase fed and food safety.

In addition to improve the efficiency and sustainabilty of production mean also challenges bot at global and national level. Accordingly, we are focusing on the following areas: **(i) The effects of extreme environmental effects on feed production and feed quality, including the analysis of nutritional value of cereal varieties, resistant to biotic and abiotic stress;**

Effcets of heat stress on the metabolism and nutrion of broiler chcickens. (ii) Food safety aspects of animal nutrition with special emphasis on the mycotoxin content of feeds. (iii) Nutritional aspects to reduce the amonia **emission of farmed animals**; (iv) Development of new feeding technologies based on industrial byproducts and **replacement of imported soybean by protein sources produced locally**; (v) Improving the quality of animla products by nutrition (vi) Improving gut health and finding alternatives of antibiotics in animal production, using next generation sequencing (NGS) to get more understandings on the feed and gut microbiota interactions.
The team lead by Prof. Dublecz has been studying various nutritional aspects of pork, poultry, beef cattle, milking cow, horse and fish production. The personal skills and the infrastructure required (laboratories, animal houses, feed mill etc.) for these studies are available at the departement of Animal Nutrition and Nutritional Physiology.

Research Area #3: Applied cell biology
Leader: Szabolcs Tamás Nagy, DSc

The cell analysis laboratory located at the Georgikon Campus is not only uniquely equipped among those in Hungarian universities with agricultural profile, but up-to-date at international level as well. The laboratory is capable of meeting the needs not only of our university, but those of the Middle European region as well.
The main fields of the laboratory are spermatology and stress-physiological, cytological studies. Modern cell analytical infrastructure, such as flow cytometry are precise tools for the analysis of spermato- and spermiogenesis, as well as that of the physiological functions of sperm cells. It can be used for the quality control of sperm samples to be used for artificial insemination, the analysis of the chromatin and plasma membrane integrity of sperm cells or the functional status of their mitochondria. A new research area is the adaptation of the so-called 'new generation cytometry', automated data analyses in R-environment to spermatology studies.
In addition to the above, experiments can be performed in the lab in all three research areas of FDS, including **animal production and animal health** (cell cycle studies, udder health analyses, gut microbiome studies), **plant production** (ploidy analyses, genome size estimation, pollen analyses), **food industry** (cell counts of brewer's yeast) and **environmental studies** (water quality, ecotoxicology, soil microbiology).
The lab participates in a number of projects involving other departments of the campus, for instance the rapid, automated analysis of microbial communities, studies on the effect of heat stress on the germ cells of animals with external fertilization, or fast genome size estimation for several animal and plant species.

Research Area #4: Fisheries & aquaculture
Leader: László Orbán, CSc

The Georgikon Campus of MATE is located in the vicinity of Lake Balaton, and this fact makes our research related to native fishes and their environment relevant. Research related to fish biology and aquaculture is often connected to both animal production and environmental sciences. **As the factors related to environment, water chemistry and hydrobiology affect the fish fauna of natural water bodies and fish stocks produced in ponds or intensive aquaculture systems the same way. Therefore, in projects related to fisheries and fish production one must pay attention to environmental conditions.** Even the rapidly spreading advanced intensive aquaculture systems keep opening up questions, like increased parasitosis, quality of the effluents from farms, the sustainability of feeding, the level of

energy usage, production and storage of quality feeds or the reduction of stress affecting the fish, that can only be answered by integrating these two research fields.
The vicinity of Lake Balaton and the 'ramsari areas' of Little-Balaton, in addition to several hundred smaller water bodies of Western Pannonia makes it our responsibility to analyze the production and environmental aspects of aquaculture together. Moreover, we are the university campus located closest to the Adriatic Sea, teaching both agriculture and environmental sciences.
This research field has been strengthened considerably with the recent formation of the Frontline Fish Genomics Research Group. The modern, high throughput approaches used by their team open up the possibilities for such new approaches that will allow for studying new aspects of the above problems. Members of the team are involved in the education of courses related to aquaculture, thereby assuring rapid transfer of the results achieved to the students.

PLANT PRODUCTION AND HORTICULTURE

The main educational goals of the Doctoral School in these project areas are as follows: (i) understanding the latest achievements of international research; (ii) performing research and applications connected to these results; and (iii) to disseminate this knowledge to the students, rendering them capable of good quality research and publications. Although our Research Areas would be able to function independently, we specifically aim for their cooperation resulting in joint research and applications.

Research Area #5: Crop production, soil fertility and environmental impact of soil management
Leader: Zoltán Tóth, PhD

Biomass production is an important task of crop production. It can be achieved and maximized through the proper management and optimization of ecological systems. Based on the long-term field experiments performed over the past decades, we have several **opportunities to increase the plant and climatic potential and that of the productivity of crop production**, to achieve more stable yields and to improve quality. In this Research Area, we are analyzing: the characteristics of the assimilation system; the process of product formation under different agrotechnical conditions; the connections between primary biomass and product yield; those among production conditions, primary biomass, soil biology and nutritional status of soils; possible replacement of certain agrotechnical conditions; **utilization of agrometeorological data; sustainable agrotechnical methods**; the patterns of soil productivity and other indicators in several decade-long experiments; certain issues of the sustainability of farming systems and soil management; and the interactions between the genotypes of plant species and the agrotechnics.
Soil is the most basic means of production of agriculture. However, its role is far more complex than that due to its ecological functions, including many ecosystem services. It is also part of the biosphere and therefore it also fulfills functions of conversion, filtering and buffering agent. The soil is not separated from other parts of the environment in its production function and as part of the biosphere. As there is a continuous flux of materials and energy among the soil, the surface-based and the subsurface water bodies as well as the atmosphere, **this system must be analyzed as a whole in** when aiming for increased efficiency of production or the protection of other parts of the environment. In this Research Area we

intend to prepare the students for better understanding of the interactions in the soil-plant-climate system through providing the necessary knowledge and the modern research methods.

Research Area #6: Horticulture
Leader: Zsolt Polgár, CSc

Horticulture is the most colorful and most diverse area of Hungarian agriculture. It involves production of vegetables, fruits, grapes, ornamental plants and medicinal herbs. Its diversity makes it possible for us the efficient utilization of our regional agroecological potential and all research that support this goal. In FDS, we have several decade-long expertise in **potato- and grape breeding, variety maintenance, production of propagation materials** and research on the related **production technologies**. The primary goal of our breeding programs is the collection, maintenance and utilization of genetic resources in order to develop varieties showing increased tolerance against biotic and abiotic stresses with high productivity and quality. The **students participating in the** education **can get acquainted with** the execution research methodology of pathological, nutrient and water utilization tests that are an integral part of the breeding work, the testing the inheritance of these traits and the identification and markering possibilities of the influencing genes. In case of potato, important research directions are the analysis of internal quality, storage physiology and processing and consumption quality of the tubers. Our studies related to production technology development covers the assessment of application of soil- and plant-conditioning agents, agrotechnical factors such as nutrient replenishment, plant density, applied plant protection, in connection to certain yield elements and quality (number, size distribution and consumption quality of tubers). **In our research, we can rely strongly on the utilization of the extremely wide genetic background available in our gene bank collections, which enables the breeding of new varieties that can meet the challenges of the present time** (suitability for organic farming, competitive cultivability, processing industry needs).

Research Area #7: The biology and ecology of plant pests and integrated protection against them
Leader: Gabriella P. Kazinczi, DSc

The protection of cultivated plants is exceptionally important, as the total amount of final products is reduced by an estimated 36% due to the presence of pathogens, pests and weeds. The collection of biological knowledge and development of the methodological arsenal are essential for the environmentally friendly plant protection which is considered to be one of the most important task for the sustainable plant production. The two main principles of practical plant protection are: 1.to understand the biology and ecology of pests and 2. to develop innovative technics and materials for the effective control.
One of the biggest challenges of plant protection in the 21st century is to preserve the safety of agriculture and contribute to the production of high-quality food products. The use of materials expressing their effect within a narrow spectrum, are able to protect the beneficial and neutral living organisms. **Approaches based on biological protection and so-called biopesticides** may allow for reduction of traditional synthetic pesticide use. However, both **deeper knowledge of pathogens, pests and weeds and that of their environment and ecology are believed to be essential** for this process.
The exponentially increasing number of invasive alien species (IAS) creates a considerable challenge for the experts working on plant protection. The appearance of invasive species, regular follow-up of their distribution and assessment of their damage through a national

monitoring network are combined with meteorological data to yield a multi-year database that in turn will allow for the development of suitable strategies of protection. **The most successful area of biological plant protection is protection against pests** that is not limited to closed system, but can also be applied on the fields nowadays.
FDS has a tradition for successful projects with enthomopathogen nematodes. In addition, we also analyze the **effects of traditional pesticides on beneficial and neutral insect species.** Pesticide resistance monitoring and development of alternative methods are also among our priorities.
In the area of herbology, we have developed a **unique collaboration on molecular herbology with colleagues working on Research Area #8.** The most important topics are as follows: (i) **analysis of weeds resistant to herbicides with the tools of molecular biology; (ii) rapid detection of weed biotypes resistant to herbicides**; (iii) **molecular monitoring of the distribution of weed biotypes resistant to herbicides;** and (iv) **comparative analyses of certain invasive weed species (s**ubspecies) (e.g.species and subspecies of the Panicum genus) by tools of molecular genetics. In addition to the conventional biomass productionapproaches, we also analyze the plant – pest relations and the responses of plants to biotic stress factors with innovative approaches, including biophoton emission as well as combined analyses with platforms of molecular biology and plant physiology, and relate them to their responses given to the abiotic stressors caused by climate change (in collaboration with researchers from the Kaposvár Campus).
One of the possibilities of environmentally friendly plant protection is **selection for lines resistant to certain pathogens**. The analysis of host-parasite connections will lead to the identification of the potential sources of resistance, what in turn might result in selection/based generation of resistant varieties. This may be especially important in case of viral pathogens, where chemical plant protection is lacking. There are a number of joint innovations aiming for the generation of resistant plant lines through selection under the umbrella of FDS.
We have unique projects aiming for the analysis of weed – virus relations, the role of weeds in the virus epidemiological chain as well as the biological decline of weeds due to viral infections. For the identification of viruses in these studies, we employ not only biological, serological and molecular (RT-PCR-based) approaches, but high throughput sequencing platforms that are capable of determining of the metagenome of the whole plant.
In the **environmentally friendly integrated plant protection system**s, the protection strategies must be based on forecasts of pests that are based on physiological and ecological data. No sustainable agriculture production can be achieved without basic and applied research supporting these goals. **Integrated plant protection** must include all types of methods: physical, mechanical, agrotechnical, chemical and biological alike. Application of an environmentally friendly chemical plant protection systems is among the primary goals of sustainable plant protection.

Research Area #8: Plant selection, genetics and agrobiotechnology
Leader: János Taller, PhD

The rapidly developing areas of molecular selection and plant biotechnology are offering new opportunities to compliment traditional selection methods. Research activities aiming to increase genetic diversity in plant selection have been intensified in order to maintain **sustainable development** and **ecological balance**. The main purpose of these research activities is to provide modern and efficient genetic and biotechnological training both in theoretical and practical areas by building onto the foundation of successful national and international practice for the future experts of plant selection and seed production.

The primary focus of our research is selection-based increase of **tolerance against biotic and abiotic stress** that includes molecular detection of genetic diversity, Marker Assisted Selection, as well as mapping and use of resistance genes in various selection programs.
The societal and economical challenges of our era, the extremely rapid development of genetics and plant selection make the theoretical and practical education at the state-of-the-art level necessary at the universities. Our students are expected to meet these demands and to gain the knowledge necessary for the overview of the field by synthesizing the vast knowledge of genetics, selection, biotechnology and biometry.
In addition to the basic techniques of genetic engineering and plant biotechnology (e.g. PCR, gene cloning, or micropropagation) our students can also become familiar with the practice of DNA library generation, **high throughput sequencing or NGS on an Illumina NextSeq 500 machine, quantitative PCR, microarray technology (Infinium platform)** and genome engineering. These experiences, together with the bioinformatic knowledge necessary will make a substantial contribution to the improvement of the theoretical and practical readiness of our students. As most Hungarian institutions tend to outsource their NGS- and microarray-based needs to companies or labs based abroad, **the use of these 'cutting edge' technologies will have the potential to make major contributions to the international competitiveness of our students** and will help them to keep up with the technological development.

Research Area #9: The effect of environmental factors (e.g. temperature, length and spectrum of illumination) onto the development and abiotic stress tolerance of plants
Leader: Gábor Galiba, DSc

D Due to their sessile nature, **plants are forced to adapt to their environment**. Perhaps the best example for this process, is the adaptation of herbaceous and woody plants of the Northern hemisphere to the harsh winters. Although the most important component of the several week-long hardening processes is the exposure to non-freezing cold temperatures, the shortening of day length and a change in the light spectrum also affect the level of **frost resistance** significantly. It is possible to increase the frost tolerance of winter wheat and barley only by the modification of the incident light spectrum without applying any additional cold treatment. The main goal of our research is to elucidate whether the modified spectrum affect the metabolism of microbes like cyanobacteria or algae similarly to the higher plants. By the investigation of the responses of organisms from different taxonomic categories, a generally applicable model could be developed to help the interpretation of the underlying hormonal, transcriptional, and lipidomical changes of modulated light spectrum induced stress tolerance.
Light is one of the most important factors affecting the **ontogenesis of plants** (germination, growth, flowering, fruit development) as it is an essential source of energy. Development is affected by the intensity and wavelength of light, as well as the length of the day too. Plants sense the signal of light through their photoreceptors: phytochromes detect red and far red light, whereas phototropins and cryptochromes detect blue and ultraviolet light. Sensing initiates a signal transmission process that regulates the expression pattern of many gene sets, resulting changes in growth, biomass production, development, vegetative/reproductive transition and crop yield. These processes can be experimentally manipulated in plant growth chambers equipped by modern LED light sources, because in this case both the light intensity and the spectra could be modulated. Thus, **environmental signals strictly coordinate molecular pathways controlling plant development.** This shows that **meteorological factors studied by environmental sciences do affect the growth, development and productivity of plants.**

By the elucidation of the details of light signaling could led to the application of special illumination programs what will result not only an improved plant productivity but also an improved fruit quality. In summary: the main goal of our research area is to better understanding of these connections in order to **promote environmentally conscious crop production.**

ENVIRONMENTAL SCIENCES

In the broad area of environmental sciences, there are ample possibilities for the analysis of both biotic and abiotic elements that involve all three areas. As living organisms are tightly connected to their environment and cannot be analyzed without considering their surroundings, therefor the connection of the three main areas of FDS cannot be questioned at the level of education either.

Research Area #10: Toxicology
Leader: Péter Budai, PhD

Toxicological studies at FDS are performed in several directions. **Chemicals used to protect plants against pests can cause substantial environmental harm** by threatening the health of living organisms. In our ecotoxicological studies, we study the effects of individual pesticides, their combinations with each other and/or with heavy metals onto bird (chicken, pheasant) embryos developing within the eggs. **When persistent metals, such as Hg, Pb or Cd, are released into the environment**, they can enter the bodies of those animals that have not had direct contact with these metals. These **environmental pollutants can be accumulated** in the body of these animals due to biomagnification. Data collected from bird tissues/organs (e.g. feather, liver, kidney, bone and muscle) are ideal for monitoring the **heavy metal pollution of a biotope**, as birds are at higher levels of the food chain, they collect their food from a larger area and they tend to occur at large density even at heavily contaminated areas. This is an important area of the **ecotoxicological studies**.
The main purpose for the introduction and application of **alternative toxicological methods** is to replace the widely applied *in vivo* toxicological applications. The current alternative toxicological techniques are based on irritation and they are unable to replace the *in vivo* methods. In order to make them capable for this, the number of chemicals tested must be increased. Although *in vitro* data for the chemicals used in agriculture are limited, many of these compounds cause irritations, thus their analysis will contribute to a database that will be useful for the authorities in the future.
The third research area deals with **toxicological studies that aim to prevent the health of farm animals**. Here, we have the opportunity to study the effects of toxic substances in the feeds by chronic oral toxicity studies in vertebrates.

Research Area #11: Components and effects of abiotic environment
Leader: Angéla Anda, DSc

Projects connected to the elements of abiotic environment, i.e. soil, air and water, can be selected. Water as an abiotic component plays a role in studies of evaporation (Lake Balaton). With the inclusion of **plants and transpiration**, the complex system of nature can be analyzed as whole. **These projects are tightly connected to those of plant production and**

horticulture, as transpiration of produced plants is a very important issue. Connections between plants and their environment can be analyzed at several levels, including studies on the effects of global warming by simulation models. With these models, the reactions of crops onto the changes in their environment can also be analyzed. **A good example for the connections between animal production and environmental sciences is the analysis of the effect of grazing animals onto their environment.**

Research Area #12: Living organisms in the agricultural environment
Leader: Előd Kondorosy, CSc

Studies on the most important pests of plants and animals are especially important for agricultural production. They include the biology of various pests, their damage caused and the protection against them. Students can perform faunistic surveys on the fields of various crops. An important goal is the development of new methods of detection and protection that could allow for **substantial reduction of the pesticide load of the environment.**
These methodologies come from an essential part of the area of **protection of agro-environment.** An essential component of basic studies is the clarification of taxonomic issues, this can be done currently in the superfamily of seed bugs (Lygaeoidea).
Multi-level interactions of plants, animals and their environment are analyzed by quantitative ecological models (e.g. food chain networks, turnaround of elements in the environment, gene-to-gene theory, co-existential and co-evolutional phenomena). Accordingly, one of our research projects deals with infra/ and supra-individual diversity, qualitative and quantitative production as well as natural value and vegetation dynamics analyses of wet ecosystems and grasslands.
Taxonomical studies for plant protection from a **link between plant production and horticulture and environmental sciences.** However, they are also tightly linked to studies on animal production as well. The studies on seed bugs target a smaller clade that contains known pests of crops, cotton and ornamental plants. **Our ethnobotanical studies are undoubtedly interdisciplinary, as they analyze the land usage of classical plant and animal production that exists in harmony with nature and environment.**

Research Area #13: Analysis and mapping of factors affecting various functions of soils in order to support the development of strategies for climatic adaptation and damage control
Leader: András Makó, DSc

The most important goal of the water policy of the European Union is to improve the quality of water resources on and below the surface using the available scientific knowledge. These water resources are in close connection with various soil layers saturated with water to a different level. The **hydrophysical properties of soils** (e.g. their absorptive, transporting and holding capabilities for water) are dependent on their section structure and stratification as well as the chemical, physical, mineralogical and biological properties. These in turn are essential factors for the water resources accessible for agricultural activities, as well as processes leading to soil degradation under extreme circumstances, such as floods and droughts. Therefore, improving our knowledge about the **hydrophysical properties of soils and methods of their quantification and/or estimation** are of increasing importance. This is one of our primary research projects, with special focus on the connection of soil structure and its porosity.

Combined environmental effects that occur on poor soils with degraded physical and biological status during droughts or those that can be experienced with soils saturated with water of poor quality and loaded with contaminants are especially important from the point of view of plant and environmental protection. Global issues with water quality include the increased nitrogen content of inland waters – often due to increased fertilizer use, animal production or irrigation with treated sewage waters – or the increased levels of toxic micropollutants caused by industrial activities. **Contaminations caused by organic liquids** are especially important factors that threaten the quality of soils and their waters. Among them the anthropogenic factors the most dangerous and most toxic ones are the chlorinated hydrocarbons that are used as solvents in the chemical industry. Although **byproducts of the petrol industry** are less pollutive than chlorinated hydrocarbons, due their sheer quantity used their risk may exceed those of the former.
Based on the above, there is an increasing need to improve our knowledge about the transport, absorption and transformation processes in soil in order to be able to make the right decisions regarding the prevention of spread of pollutions or **remediation of polluted soils**. **Various computational models** may provide help to identify the most suitable and most economical remediation and monitoring strategies. In our research we are planning to study the interactions of soils and their pollutants, to refine our models of the spreading of pollutants from the point of view of soil analysis and soil physics, and the development of methodologies allowing for the generation of maps for polluted soils at various different resolution.

Research projects offered by the Festetics Doctoral School

Students with an MSc degree can apply for PhD studies by filling and submitting the form that can be either obtained in person from the representative of the Doctoral and Habilitation Center at Georgikon Campus (Ms. Mercédesz Budai-Koncz) or downloaded as a soft copy from the website of the Hungarian University of Agriculture and Life Sciences (from here MATE). The supplement of the form contains the list of those documents that must be attached to the application. The Doctoral Rules of MATE describe the conditions of acceptance as well as the evaluation criteria (suitability, scientific achievements, grade of Thesises, etc.).

https://uni-mate.hu/hu/kepzesek/doktori-kepzes

The actual project offers can be found in the database of the National Doctoral Council (ODT).

Model curriculum with the requirement of FDS

The research and educational plan of accepted graduate students will be put together on an individual basis by keeping the specific needs of the students in mind. The supervisor of the student and the head of FDS will submit the program together to the Council of FDS at the beginning of the training. The Council will evaluate the program and will decide on acceptance. In addition to the compulsory courses required by FDS, students are allowed to obtain credits from elective courses offered by FDS or any other doctoral school in the

country. Subsequent modification of the program, if any, is subject of the approval the Council of FDS.

Our model curriculum was put together based on two government decrees: one that deals with higher education (CCIV/2011) and the other that deals with doctoral schools, the process of doctoral processes and habilitation (387/2012.; XII. 19.). It describes a potential progress of development broken down into annual portions.

Trainings that started prior to September 1st, 2016

The model curriculum contains the maximum of 180 credits that can be obtained from the three different areas (i.e. education, teaching and research) broken down annually.
Students are expected to earn 50 educational credit points (*Table 1.*). Teaching credits are not compulsory and it can be replaced by extra credits earned at the other two areas. Self-funded students are expected to gain 50 educational credits; however, they are not required to attend the lectures. Instead they can request personal consultation from the teacher responsible for the course. The detailed list of courses can be found at the homepage of FDS.
In addition to the compulsory courses required by FDS, students are allowed to obtain credits from elective courses offered by FDS or any other doctoral school in the country (must be pre-approved by the Council of FDS).

Table 1: Minimal credits earned at FDS

I.	**Studies**	**Year #1**		**Year #2**		**Year #3**		**Sum**
		weekly	**annual**	**weekly**	**annual**	**weekly**	**annual**	
	CREDITS[o]		**28**		**20**		**2**	**50**
	Contact hours	**15**	**210**	**10**	**150**	**1**	**15**	
	Individual work (hours)	**42**	**630**	**30**	**450**	**3**	**45**	
	Total	**56**	**840**	**40**	**600**	**4**	**60**	**1500**
II./a	**Publications**	**Year #1**		**Year #2**		**Year #3**		
	CREDITS	**10**		**16**		**38**		**64**
	Total hours	**300**		**480**		**1140**		**1920**
II./b	**Essays**							
	CREDITS	**7**		**8**		**18***		**33**
	Hours	**210**		**240**		**540**		**990**
III.	**Electives (education[oo]/research)**							
	CREDITS [ooo]	**15**		**16**		**2**		**33**
	Total hours	**450**		**480**		**60**		**990**
IV.	**Sum Total**							
	CREDITS per year	**60**		**60**		**60**		**180**
	Hours per year	**1800**		**1800**		**1800**		**5400**

* Final exam
[o] One contact hour per week earns two credits; 15 weeks per semester
[oo] One hour educational activity per weeks earns two credits
[ooo] Maximum 45 credits for educational activities

Credits for publications

Type of publication	*Credits*
a) research paper in foreign journal with impact factor	50
b) research paper in foreign, refereed journal[1]	30
Minimally required:	60
c) research paper in native language[2], in peer-reviewed journal	10
Minimally required:	10
d) paper published in full at conference proceeding	10
Minimally required:	10

[1] this can be replaced with a research paper published in a foreign journal with impact factor
[2] foreign students can use a publication in English instead

Graduate students participating in the program will obtain an absolutorium after obtaining 180 credit points and meeting the required scientific milestones. In order to obtain the degree, they must have the required number and quality of publications (at least 80 credits) or be in possession of a letter of acceptance from the Editor of a suitable journal.

Minimal criteria for the absolutorium

Educational activities	**min. 50 credits**
Research activities	**min. 113 credits**
Periodic reports	33 credits
Publication activity	min. 64 credits
Teaching activities	**max. 45 credits**

Minimal criteria for the PhD

1. With teaching activities

Educational activities	**min. 50 credits**
Research activities	**min. 113 credits**
Periodic reports	33 credits
Publication activity	min. 80 credits
For teaching	**min. 17 credits**
Grand total	***min. 180 credits***

2. Without teaching activities

Educational activities	**min. 50 credits**
Research activities	**min. 130 credits**
Periodic reports	33 credits

Publication activity	min. 97 credits
Grand total	***min. 180 credits***

Scientific performance of the students is being judged regularly, the process contains (i) annual oral presentations in front of a committee and (ii) the assessment of published papers. Oral presentations consist of the research data produced by the students during the previous year. In addition to the presentation, the supervisor also confirms the progress of the student at the end of the first semester by signing the progress report. The final presentation contains the progress achieved during the whole three-year period. The committee then reviews the performance of the student and makes the decision on the continuation. In case of an acceptance, the total number of credit points does not depend on the mark received. Should the committee reject the presentation, it should be repeated at a later date.

Each PhD student is required to attend three live PhD defenses per year in person or through the internet. Proofs of attendance will be part of the annual reports. Should the student have less than three proofs of attendance, the committee has the right to reduce her/his credits accordingly. Exemption will only be given in unforeseeable, serious situations (i.e. study period abroad or long-term hospitalization).

In order to meet the conditions of quality assurance, FDS pays close attention to regular publication activities and research papers published in internationally recognized, Tier 1 journals. In order to meet the criteria for publication, the paper must be peer-reviewed by a journal with a long-standing Editorial Board, it must have a Reference List and its Abstract must be in English (in case of papers written in another language). Conference papers cannot be used to replace published papers.

The student must have at least one first-authored paper published on her/his publication list. Lectures without page numbers in Proceedings cannot be claimed as published papers, they can only be considered as Abstracts.

Prior to an Open Defense, the candidate must submit her/his publication list to the head of FDS. The list must be accompanied by a signed letter from the supervisor, who declares that the candidate met the criteria for defense. The Council of FDS then discusses the application and makes a decision.

Trainings that started after September 1st, 2016

The research and educational plan of accepted graduate students will be put together on an individual basis by keeping the specific needs of the students in mind by 30th of September as the latest. The supervisor of the student and the head of FDS will submit the program together to the Council of FDS at the beginning of the training. The Council will evaluate the program and will make a decision on acceptance. In addition to the compulsory courses required by FDS, students are allowed to obtain credits from elective courses offered by FDS or any other doctoral school in the country. Subsequent modification of the program, if any, is subject of the approval the Council of FDS.

According to our model curriculum, FDS expects students to earn 50 educational credit points (*Table 2.*). The training contains two periods of two years each. During the first (educational and research period), and during the second (research and dissertation period) a 120 credit

points each (i.e. a grand total of 240 credit points) must be earned. *Table 2* shows the number of credit points of three types (educational, reports and publications) for each semester. Teaching credits are not compulsory and it can be replaced by extra credits earned at the other two areas. Self-funded students are expected to gain 50 educational credits; however, they are not required to attend the lectures. Instead they can request personal consultation from the teacher responsible for the course. The detailed list of courses can be found below (*Table 5*).
In addition to the compulsory courses required by FDS, students are allowed to obtain credits from elective courses offered by FDS or any other doctoral school in the country (must be pre-approved by the Council of FDS).

Table 2: Minimal credits to be obtained at FDS

Educational and research period (120 credits; 2 years)					
Semester	I.	II.	III.	IV.	Credits
Education	20	15	10	5	50
Reports	5*	5	5*	15	30
Publications	5	5	10	20	40
Total					**120**
Research and Dissertation period (120 credits; 2 years)					
Reports	10*	10	10*	20	50
Publications	10	20	20	20	70
Total					**120**
Grand total					**240**

*Written report

A maximum of 45 credits can be earned for educational activities.

Credits for publications

Type of publication	***Credits***
a) research paper in foreign journal with impact factor	50
b) research paper in foreign, refereed journal[1]	30
Minimally required:	60
c) research paper in native language[2], in peer-reviewed journal	10
Minimally required:	10
d) paper published in full at conference proceedings	10
Minimally required:	10
e) conference abstract published	5

[1] this can be replaced with a research paper published in a foreign journal with impact factor
[2] foreign students can use a publication in English instead

Scientific performance of the students is being judged regularly, the process contains (i) annual oral presentations in front of a committee and (ii) the assessment of published papers. Oral presentations consist of the research data produced by the students during the previous year. In addition to the presentation, the supervisor also confirms the progress of the student

at the end of the first semester by signing the progress report. At the end of the second year, presentation contains the progress achieved during the whole two-year period. The committee then reviews the performance of the student and makes the decision on the continuation. In case of an acceptance, the total number of credit points does not depend on the mark received. Should the committee reject the presentation, it should be repeated within seven (7) days. In those cases, where the performance lacks essential elements that cannot be rectified within seven days, the student must submit an appeal to the Council of FDS that will make a decision on the case.

Each PhD student is required to attend three live PhD defenses per year in person or through the internet. Proofs of attendance will be part of the annual reports. Should the student have less than three proofs of attendance, the committee has the right to reduced her/his credits accordingly. Exemption will only be given in unforeseeable, serious situations (i.e. study period abroad or long-term hospitalization).

After completing the first two-year period, the students must pass a Complex Exam in front of a committee. The exam consists of two parts: in the first (theoretical part) the knowledge of the student is assessed. During this part, the student is examined on the basis of two subjects (see *Table 3* for details). In the second (dissertation part), the scientific progress of the student is analyzed.

Table 3: Courses for the theoretical part of the Complex Exam (*Animal production*, ***Environmental studies*, Plant production and Horticulture**)

Main courses	**Auxiliary courses**
Biological and ecological aspects of animal production	*Methodologies of the research area*
Physiological and biochemical foundation of sustainable animal production	*Methodologies of the research area*
The most important biotic and abiotic elements and processes of the environment	***Methodologies of the research area***
Crop production	**Methodologies of the research area**
Factors affection soil productivity	**Methodologies of the research area**
Horticulture (potato, vegetables, fruits, grapes and ornamental plants; sustainable plant production)	**Methodologies of the research area**
The biology and ecology of pests and resistance against them	**Methodologies of the research area**
Plant selection, genetics, plant biotechnology	**Methodologies of the research area**

During the second part of the Complex Exam, the student describes the background of her/his research field, presents the data collected so far, the plan for publications as well as the timeline for the Thesis and the publications. The presentation must also show the scientific relevance and innovational content of the data, the technological motivation of the research work (if applicable) and the potential applicability of the results. The students must submit a short summary of her/his results as well as the list of published and accepted papers in electronic format one week before the exam date.

A Complex Exam is successful (passed), when the majority of the committee accepts both parts as successful. In case of an unsuccessful exam, the student will be given an opportunity to repeat that part(s) once during the exam period. Should the repeated exam be unsuccessful again, the status of the student ceases to exist on that day. The result of the Complex Exam is not part of the marking of the Doctoral Degree, however, its successful passing is a pre-requisite of the entry of the second period (research and dissertation period).

After passing the Complex Exam, the student earns the right to take part in the second part of the process. The aim of that part is to earn the PhD degree. The minimal condition for obtaining the absolutorium is to earn 110 credit points from publications and 80 credit points from reports. In order to receive the degree, the student must have all her/his papers published or at least accepted by the journal (as proven by an official letter from the Editor addressed to the student or supervisor).

According to the Doctoral Rules of MATE, the student must submit her/his Thesis within three years from the date of the Complex Exam. Under special circumstances, as described by the second paragraph of Nftv. 45. §, the process can be extended by a total of one (1) year according to the rules of the doctoral process. The status of the student can only be suspended for the maximum of two years.

Summary of publication requirements

The minimal requirements for obtaining a PhD degree a student at FDS must have:

- three registered* or at least peer-reviewed** scientific publications out of which one must be in a journal with impact factor;
- one of the above publications must be a first-authored paper in an international journal (in foreign language, typically English);
- a conference lecture or poster that has been published (at least four pages of length).

* Registered journals: Those scientific journals that are listed either by Scopus or by the Agricultural Section of the Hungarian Academy of Sciences (MTA).

** Peer-reviewed publication: A paper that has been published by a journal that (i) has a permanent Editorial Board; (ii) has the submitted manuscripts reviewed by experts of the field; (iii) publishes papers with a full Reference List; and (iv) in case of a Hungarian journal has an English summary.

The detailed list of courses can be found below (*Table 5*). In addition to the compulsory courses required by FDS, students are allowed to obtain credits from elective courses offered by FDS or any other doctoral school in the country (must be pre-approved by the Council of FDS).

Table 5: The courses of FDS with the number of credits and name of responsible teacher

Courses Listed according to the research area of the responsible teacher	**Credits**	**Tantárgyfelelős**

Compulsory for all three research areas		
Data collection and analysis	8	Dr. László Menyhárt
Environmental problems and their solutions in agriculture	8	Dr. Angéla Anda, Dr. Ferenc Husvéth, Dr. Zsolt Polgár
Animal production		
Compulsory courses*		
Genetics of animal production	4	Dr. Péter J. Polgár
Basics of animal nutrition	6	Dr. Károly Dublecz
Basics of cell biology	4	Dr. Szabolcs Tamás Nagy, Dr. Péter Szeglet
Phisology of animal production	6	Dr. Ferenc Husvéth
Fish biology and aquaculture	4	Dr. Havasi Máté, Dr. Specziár András

Elective courses		
Physiological basis of environmental adaptation in animals	6	Dr. Ferenc Husvéth
Environmental analytics	4	Dr. László Wágner
Ornamental fish production	4	Dr. Máté Havasi, Dr. Gábor Beliczky
Environmental aspects of aniumal nutrition	4	Dr. László Pál, Dr. Hedvig Fébel
Nutritional aspects of sustainable poultry nutrition	4	Dr. Károly Dublecz
Poultry physiology and anatomy	4	Dr. László Pál
Poultry nutrition	6	Dr. Károly Dublecz
Poultry production	4	Dr. Gellért Kovács
Poultry breeding	6	Dr. Gellért Kovács
Poultry products and their certification	4	Dr. Gellért Kovács
Basics and application of developmental biology in animal production	4	Dr. Szabolcs Tamás Nagy, Dr. Szilárd Bodó
Meat processing and quality	4	Dr. Péter J. Polgár
Ruminant nutrition	4	Dr. Ferenc Husvéth, Dr. Hedvig Fébel
Husbandry of small ruminants	4	Dr. Péter J. Polgár
Horse nutrition	4	Dr. Ádám Bartos
Molecular genetic methods in animal production	8	Dr. István Anton
Instrumental analytics	4	Dr. László Wágner
Bovine husbandry	4	Dr. Péter J. Polgár
Bovine production	6	Dr. Szabolcs Bene
Bivone products and their certification	4	Dr. Péter J. Polgár
Feed and food analytics	4	Dr. László Wágner
Feed and food certification	4	Dr. László Wágner
Scientific communication I.	2	Dr. Szabolcs Tamás

		Nagy
Experimental design	2	Dr. Szabolcs Tamás Nagy
Special methods in aquaculture	6	Dr. Miklós Bercsényi Dr. Gábor Beliczky
Advanced communication in science	4	Dr. László Orbán
Ethologie und Weidehaltung	4	Dr. Péter J. Polgár
Connections between gut metabiome, health and environment	4	Dr. Andor Molnár
Introduction to metagenomics	4	Dr. Valéria Farkas
Environmental Sciences		
Compulsory courses*		
Animal taxonomy and morphology	6	Dr. Előd Kondorosy
Environmental analytics	4	Dr. László Wágner
General principles of toxicology	4	Dr. Péter Budai
Introduction to cell biology	4	Dr. Szabolcs Tamás Nagy, Dr. Péter Szeglet
Molecular basis of abiotic stress tolerance in plants	6	Dr. Gábor Galiba
Processes in the soil-plant-atmosphere system	6	Dr. Angéla Anda
Elective courses		
Meteorological basis of air quality control	4	Dr. Zoltán Dunkel
Introduction to molecular biotechnology	6	Dr. Gábor Galiba
Basic concepts in plant population biology	4	Dr. Judit Bódis
Soil as a habitat	6	Dr. Miklós Dombos
Environmental effects of agrochemicals	4	Dr. Erzsébet Ihárosi
Animal protection and bioethics	6	Dr. György Sándor Fekete
Alternative methods in toxicology	4	Dr. Péter Budai, Dr. Rita Szabó
Circulation and accumulation of elements and minerals	6	Dr. Péter Szeglet
Meteorological background of climate change	4	Dr. Zoltán Dunkel
Introduction to the 'R' programming language	4	Dr. László Menyhárt
Ethno-ecology	4	Dr. Zsolt Molnár
Cytology and histology of vertebrates	4	Dr. Előd Kondorosy
Conservation of invertebrates	4	Dr. Előd Kondorosy
Pest control in vegetable culture	4	Dr. Gabriella Kazinczi
Ecotoxicology	4	Dr. István Somlyay
Native sagebrush species	4	Dr. Judit Bódis
Native grass species	6	Dr. Judit Bódis
Hydroecology	4	Dr. Tamás Kucserka
Hyperspectral data processing	6	Dr. József Berke
Interactive presentation	6	Dr. József Berke
Environmental hygiene	4	Dr. Péter Budai
Analysis of environmental effects in plant physiology	6	Dr. Éva Kincső Decsi

Environmental chemistry	4	Dr. Gábor Csitári
Introduction to environmental risk assessment	4	Dr. István Sebestyén
Environmental microbiology	4	Dr. Gábor Csitári
Agricultural engineering in sustainable plant protection	6	Dr. Béla Pályi
Data analysis of in environmental sciences using 'R'	6	Dr. József Kovács
Quantitative plant ecology	6	Dr. Péter Szeglet
Atmospheric studies	6	Dr. Angéla Anda
Limnology	4	Dr. Tamás Kucserka
Macroscopic mycology	6	Dr. Péter Szeglet
Renewable energies	4	Dr. Béla Pályi
Interpretation and evaluation of meteorological data	4	Dr. Márta Hunkár
Methodology of data collection and analysis	8	Dr. László Menyhárt
Rheology of agricultural materials	4	Dr. Béla Pályi
Pnalt- and animal-based poisoning	4	Dr. József Lehel
Plant ecology	6	Dr. Péter Szeglet
Insect physiology	4	Dr. Zsolt Marczali
Insect ecology	4	Dr. Zsolt Marczali
Salione soils	6	Dr. Tibor József Novák
Feed toxicology	4	Dr. Péter Budai, Dr. Károly Dublecz
Microbiology of soils	4	Dr. Gábor Csitári
Processing information obtained by remote sensing	6	Dr. József Berke
Spatial data collection	4	Dr. János Busznyák
Spatial information systems	4	Dr. János Busznyák
Experimental methods of toxikology	4	Dr. Péter Budai
Visual data processing in the evaluation of experiments	6	Dr. József Berke
Project management in research	4	Dr. Gábor Pintér
Plant production and Horticulture		
Compulsory courses*		
Molecular plant pathology	4	Dr. Miklós Pogány
Production of important crops	6	Dr. Sándor Hoffmann
Plant biotechnnology and its research methods	6	Dr. János Taller
Plant growth and development	6	Dr. Éva Kincső Decsi
Tillage and soil use in the soil-plant-climate system	4	Dr. Tamás Kismányoky
Elective courses		
Bioethics	2	Dr. Zoltán Alföldi
Environmental risk assessment of GMO plants	2	Dr. Zoltán Alföldi
Theory and practice of selection for resistance	4	Dr. Gyula Vida
Weed biology and ecology	6	Dr. Gabriella Kazinczi
Applied microbiology of soils	4	Dr. Gábor Csitári
Infectious genetic information	4	Dr. András Péter Takács
Molecular Plant Pathology I.	4	Dr. Miklós Pogány
Molecular Plant Pathology II.	4	Dr. Miklós Pogány

Regulatory small RNAs in plants	4	Dr. Zoltán Havelda, Dr. Éva Várallyay
The genetics of plant nutrition	4	Dr. Borbála Hoffmann
Experimental methodology of plant varieties	2	Dr. Borbála Hoffmann
Conditions affecting the quality of bread grains	2	Dr. Sándor Hoffmann
Organic matter management of soils	4	Dr. Sándor Hoffmann
Horticultural dendrology	2	Dr. Éva H. Baracsi
Integrated weed control	4	Dr. Gabriella Kazinczi
Application of zoocids	2	Dr. Sándor Keszthelyi
Experimental methodology of field science	4	Dr. Tamás Kismányoky
Oxidants and antioxidants in stress response	2	Dr. Gábor Kocsy
Breeding of vegetables and horticultural plants	2	Dr. János Kovács
Weed collection methodology	2	Dr. Éva Lehoczky
Herbological methodology	4	Dr. Éva Lehoczky
Pesticide chemistry	6	Dr. Éva Lehoczky
Germination biology of seeds	2	Dr. Sándor Záborszky
Physical properties of three-phased soils	4	Dr. András Makó
Introduction to the physics and chemistry of contaminated soils	3	Dr. András Makó
Environment and the water management of soils	4	Dr. András Makó
Agrochemicals, food safety and the environment	4	Dr. Erzsébet N. Ihárosi
Modern application technology of pesticides	4	Dr. Erzsébet N. Ihárosi
Weed flore of plant production and methods for their control	4	Dr. Erzsébet N. Ihárosi
Agrochemical methodology	4	Dr. Tamás Németh
Mobile genetic elements	2	Dr. Ferenc Olasz
Selective potato breedings	2	Dr. Zsolt Polgár
Modern methods for the physical analysis of water management of soils	2	Dr. Kálmán Rajkai
Theoretical considerations of nutrient management and dynamics	4	Dr. Katalin Sárdi
Interactions between soils and fertilizers	2	Dr. Katalin Sárdi
Experimental methodology in culture vessels	4	Dr. Katalin Sárdi
Scientific communication II.	4	Dr. Katalin Sárdi
Environmental soil chemistry	4	Dr. András Makó
International soil classification systems	2	Dr. Gergely Tóth
Talajerózió: okok, folyamatok, hatások	2	Dr. Tamás Hermann
A kártevő rovarok kémiai ökológiája	2	Dr. Gábor Szőcs
A növényi kórokozókkal szembeni rezisztencia háttere	2	Dr. András Péter Takács
Basic concepts of resistance biology to pathogens I-II..	2	Dr. András Péter Takács

Developments in Biotechnology	4	Dr. János Taller
Plant-biotechnology and research methodology I.	6	Dr. János Taller
Plant-biotechnology and research methodology II.	6	Dr. János Taller
Soil information systems and databases	2	Dr. Gergely Tóth
Soil quality and its indicators	4	Dr. Gergely Tóth
Saline soils	6	Dr. Tibor József Novák
Interactions between the root system and soil	4	Dr. Zoltán Tóth
Agro-ecological studies in a controlled environment	4	Dr. Ottó Veisz
Climate change - challenges and possibilities for safe food production	2	Dr. Ottó Veisz

***Students need to earn 10 credits from compulsory courses for each discipline.**

For detailed information on the above courses see Supplement #1.

All students must select two courses: (1) Data collection and analysis; and (2) Environmental problems and their solutions in agriculture. The latter proves the tight link among the three disciplines, as it is managed by one teacher each from the three disciplines (A. Anda – Environmental Sciences; F. Husvéth – Animal production and Zs. Polgár – Plant production). In addition to these two courses, students must select the compulsory courses of their own disciplines, plus 10 elective courses from any of the three disciplines.

The fact that several courses are being taught as a joint effort from teachers from different disciplines (e.g. Feed toxicology – K. Dublecz and P. Budai; Introduction to cell biology – Sz.T. Nagy and P. Szeglet) provides a further proof for the interdisciplinary nature of FDS.

The rest of the credits are being planned by the student and the supervisor and approved by the Council of FDS. Subsequent modification of the list can only be made with the approval of the Council.

In addition to the compulsory courses required by FDS, students are given a chance to obtain credits from elective courses offered by FDS or any other doctoral school in the country or even those obtained during a study trip abroad. However, these must be approved by the Council of FDS.

The infrastructure of Festetics Doctoral School

The essential conditions for the training must be provided by the departments, where the supervisors work. Should special needs arise for a project, the Head of Department must certify with his signature that the department will be able to meet them.

Departments providing supervisors for the FDS:

Department of Agricultural Engineering
Department of Nutrition and Nutritional Physiology
Department of Applied Fish Biology
Department of Animal Selection

Department of Precisional Animal Breeding and Animal Biotechniques
Department of Sustainable Environment
Department of Environmental Protection
Department of Plant Protection
Department of Plant Physiolgy and Plant Ecology
Department of Agronomy
Research Center of Crop Production

Official partner institutions:

- Centre for Agricultural Research, Martonvásár

Conditions for awarding the PhD degree:

- obtaining 240 credit points;
- passing the Complex Exam;
- presenting proofs for language proficiency;
- presenting the required peer-reviewed publications;
- writing summaries using the languages required by FDS;
- defending the Thesis on an open exam.

The degree will be awarded by the Doctoral and Habilitation Council of MATE based on the recommendation of the Council of FDS.