emPLANT+ COURSE CATALOGUE

ERASMUS MUNDUS MASTER PROGRAMME IN PLANT BREEDING

Contents

Joint Courses

JOINT COURSES	Description, contents, learning outcomes	Implementation:	ECTS
Pilot case	The pilot case is a case study to apply the project management tools to a breeding program. First students by group o choose a species to be ameliorated. Then, find a character or several as goal for the breeding strategy. After, they check that there is a potential market for this new variety and verify that farmers will want to cultivate it and consumers too (1-week work) To be accomplished during all the first year. Secondly students are going to define the potential market for their product (seeds), but also the market for the new variety (consumers). Thirdly they need to create a structure who is going to breed the new variety, and define the role of each student on the group in this structure (company, association...)	The introduction to the Pilot Case will take place during the Joint Integration Week where the groups will be formed based on the specialty chosen by the students for Y2. During the first year the students will work in groups with their tutors and via telephone/video conference/email. During S3 the Pilot Case will be finalized with the tutors at the host university and by telephone/video conference/email among the group members. Two juries will be organized. The first jury at the end of S1 will evaluate the content and the form of the work and especially the project management content. At the end of S2 a written report and a second presentation more focused on the breeding schema will be evaluated. At the end of S3 a jury composed of the local tutors, the Coordinators for Y1 and an expert in Project Management will judge the defense of the Pilot Case. The juries of S1 and S3 will be carried out the same day for logistic reasons.	S1: 3 S2: 2 S3: 2
Intellectual Property & Plant Breeders' Rights	The two systems (plant patent and plant breeders' right) and implication for breeder rights. Breeder's exemption and farmer privilege. From practical examples, lecturers from institutions and companies will bring pros and cons for each system. Infringement cases and violations will be analyzed. UPOV origin and historical steps. DCU and VCU notions. The transgenic varieties, the mutant and somaclonal variants will allow to introduce the notion of Essentially Derived variety (EDV). Current and potential application of molecular markers and next generation sequencing will be discussed.		S2: 2
Summer Field Camp at the end of year 1 (June)	The objective of this summer intensive program is to immerge students in two crops breeding chains. One week for a major crop such as corn or wheat and the second on a legume or fruit crop (green bean, apple). During each week students are going to go visit		S2: Appraisal

	the main actors related to breeding for the selected crop from farmers, to several breeders (diversity conservation, breeding, laboratory) or public research institutions involved in basic research , seed industry and seed multiplication farmers and maybe food industry to see the quality requirements for the specific transformation. To have a full panorama of this crop. The main learning objective is to have an integrated view of the food chain from the breeding till the final transformation of the product. Secondary objectives are to understand the different actions of breeding companies, how they integrate the requests of the consumer. To haw a deeper knowledge on at least two crops which are managed differently, as are the cereals and the vegetables. And understanding the importance of the seeds quality.		
Bio informatics	Biological databases; gene analyses, web-based analytical tools, Unix OS, functional genomics, molecular evolution, RNAseq expression analysis, annotation of new genomes.	This course will be offered via videoconference and tutorials and accompanied by tutors at the host universities. The class will be validated by a computer-based exam.	S3: 2
Big Data	Clustering, Random Forests, K-Nearest Neighbors Method/ Kernel Methods, Sparse Methods for high dimensional data. Databases (Big data) Management Distributed file systems, Hadoop, Parallel, distributed, massive data processing with Map Reduce NoSQL/NewSQL databases	This course will be offered via videoconference and tutorials and accompanied by tutors at the host universities. The class will be validated by a computer-based exam.	S3: 2

YEAR 1

Semester 1 ULS

SEMESTER 1 ULS (30 credits)	Objectives	ECTS
Cross culture & ethics	To raise awareness and develop skills around culture and its impact on behavior in international teams. Students will draw on their own experience of learning within a multi-cultural team immersed in a host culture. Reading - implementation of the method of ethics: analysis, explanation of the differentiated arguments of the ethical issue. Know how to comment - discern the positioning that appears to us most relevant and be able to account for it. Be able to justify and explain contradictory arguments.	1
Introduction to seed business	Identify several factors going to impact the way of organizing companies on a regional and global scale such a long-term activity as the breeding and the selection, in relation with transversal technologies and breeder's profiles: technological traits, biotechnologies, markets, climatic changes, natural resource limitations, exchanges between countries and continents.	2
Introduction to algorithmics	- Know how to use the fundamental structures of the algorithmics - Know how to analyze a problem and solve it with an algorithm - To implement an algorithm To use a procedural language (C language)	1
Statistics	Develop knowledge on data distribution, estimation procedures and confidence by examining the area of interval estimation. Acquire the tools to identify the appropriate statistical test to use regarding a scientific question. Perform a variety of univariate and multivariate analyses using R software (coding, data visualization, interpretation). Being able to mobilize skills in various context of data analysis.	3
Plant Reproduction systems	To be able to identify the reproduction systems of any species To understand the needs to achieve a cross in a species To understand the seed quality requirements To be able to identify the vegetative reproduction structures and manage them	2
Fundamental genetics	Master fundamental concepts of plant genetics. Being able to analyze and interpret transmission mechanisms of hereditary characters. Develop advanced knowledge on haploid organism genetics, extrachromosomal inheritance and epigenetics.	3

Breeding Strategies	To be able to define the breeding goals in the midterm and long term, reasoning the breeding strategy adapted to the objectives, species, germplasm, traits to be selected according to the dimension of the breeding program, breeding tools and selection methods.	3
Introduction to plant pathology	The objective is to study the principals of the plant-microorganisms interaction. It introduces the major plant pathogen groups (viruses, viroids, phytoplasmas, bacteria, fungi, nematodes and the higher plant parasites) and the abiotic plant stresses (caused by environmental factors). It introduces also the importance of the beneficial microorganisms (e.g. PGPR, Plant-growth-promoting-rhizobacteria & AM, arbuscular mycorrhizae). Students study the scientific classification of theses microorganisms, their detection and quantification, and the general methods of control (chemical, biological & genetic).	3
Ecophysiology	Understand and analyze how a plant population grow and develop in its environment under optimal growing conditions and under stresses. Understand the impact on crop production Introduce the crop model concepts.	2
Experimental design	- Understand the general principles of experimentation - Know the most classic devices used in plant experimentation - Perform statistical analysis of these devices - Choose the most suitable experimental device for a described situation.	3
Population genetics	- Extend the concepts of general genetics to populations. - Understand the models of population genetics. - Know how to describe a population in genetic terms. - Use these achievements in the context of biodiversity and evolution.	2
French as a foreign language	This language course aims at providing students with the necessary language tools to interact successfully in everyday life and in basic professional situations. The objective is that students get the B1 level in French at the end of the year in order to be able to get the Engineers Diploma.	2
Spanish as a foreign language	This language course is targeted at students who chose UPV as Y2 destination and who still need to bring their Spanish to a B2 level for everyday life and professional situations.	Certificate

Semester 2 ULS

SEMESTER 2 ULS (30 credits)	Objectives	ECTS
Plant Microbe Interaction	To acquire knowledge to breed for plant resistance. To be able to differentiate between the qualitative and quantitative resistance and be able to choose the most adapted breeding methods. Be able to select alternative protection methods using effectors, elicitors and beneficial microorganisms. Be able to follow the epidemiology of plant diseases, their interaction with other factors as insects and to implement strategies to keep plant resistance. Be able to identify the plant resistance gene markers and gene expression analysis with molecular markers.	5
Plant genetic resources and diversity	At the end of this course student will understand the Importance of germplasm in breeding projects. The different types of evaluation of a collection, morphological, chemical, technological, molecular and their representations. Allelic richness, diversity structure. How to manage and use the genetic diversity: core collection and sampling strategies.	2
Quantitative genetics	Basics for Quantitative genetics Definitions of qualitative and quantitative traits. Understanding major gene(s) vs polygenic control and inheritance. Analyze variance components of quantitative traits. Definition of heritability and estimates, genetic gain. Introduction to Molecular quantitative genetics and genomic selection.	3
Seed and plant production and certification regulation guidelines	Importance of quality in seed and plant development and production. Notion of seed and plant certification. Comparison of certification processes and practical achievement in different regions. Understand the importance of physiological quality, sanitary conditions and genetic conformity for seed and plant productions.	3
Breeding strategies and methods of selection	To understand the diversity of breeding strategies in several crops (continental and tropical) with several strategies: (i.e.; organic, participative) To be able to identify the needs on the market in terms of ideotype and how to achieve to reach this ideotype combining classic and molecular breeding strategies.	3
Relational Databases – Phenotyping	In this course, you will learn what is a relational database, how to create a good database model with a good relational database on Access software. How to query data on it with SQL language. A focus will be done on how to collect, to store data safely and to mobilize many data, using excel and classic database.	4

Job marketing	To be able to build up a presentation email To be able to build up a curriculum vitae To be able to build up a motivation letter To be performant during a recruitment	1
Internship + Minor Thesis	The minor thesis internship takes place in a company or research institution. It will familiarize student with a seed company and breeder position. Student have to make a minor thesis report. Discover the business sector and its environment. Work in one of the departments and understand how it works. Study a problem related to the activity. Reflect, structure and make a personal contribution which is useful to this structure	5
French as a foreign language	Following semester 1 course. Reach the B1 level	Certificate
Spanish as a foreign language	Following semester 1 course. Reach the B2 level	Certificate

Semester 1 SLU

SEMESTER 1 SLU (30 credits)	Objectives	ECTS
Introduction to Plant Biology for Sustainable Production	The course will give an introduction to the master program in Plant Biology for a Sustainable Production. The course will provide the students with a basic foundation for future University studies at the master level and a comprehension of the basic biological conditions for plant production. The course lectures, exercises and excursions cover: - basic plant biology, including plant physiology, metabolomic, genetics, and molecular genetics - conditions for plant production, covering agriculture, horticulture, and forestry. - basic statistics with relevance for the courses that follow in the master-program - an introduction to ethical argumentation, sustainable development, science philosophy and the scientific method and science	15

	communication. - scientific presentations, in oral and in writing.	
Plant Growth and Development	The course deals with developmental biology of plants and environmental constrains upon plant growth. Focus is on regulation of cell division, meristem activity, plant stem cells, embryogenesis and organogenesis, signal transduction and plant hormones. Molecular techniques such as recombinant DNA techniques, protein targeting, gene and protein expression analysis, and mutant screening are used.	15
Swedish as a foreign language	The topics range from introducing and telling about oneself to greetings, family, food, shopping, weather and telling the time. The topics also include daily activities, living, transport and the immediate surroundings. The aim is to introduce students not only to the basic structures of Swedish, but also to the Swedish way life. Simple everyday conversation is practised.	Certificate
Spanish as a foreign language	This language course is targeted at students who chose UPV as Y2 destination and who still need to bring their Spanish to a B2 level for everyday life and professional situations. Students will learn Spanish at the rate of 2 hours per week. In addition to classroom instruction, students will realize interactive assignments. This course is carried out in close collaboration with UPV so as to ensure that the students obtain the language level needed.	Certificate

Semester 2 SLU

SEMESTER 2 SLU (30 credits)	Objectives	ECTS
Plant Biology for Breeding and Protection	The course focuses on plant biology for breeding and protection in a global perspective. Bioinformatics with focus on analyzing –omics data to improve and better understand plant breeding and protection will be an important part of the course. The course content consists primarily of the following points: - Process of plant breeding (overview, genetics and genetic resource enhancement etc.) - Genotype-by-environment interaction and adaptation to environmental stresses. - Pre/Breeding programs in Sweden and worldwide - Biology of plant pathogens and pests - Plant disease diagnosis, management and control - Plant pathogen interactions - Plant immunity	15

	- Modern breeding tools, including GM and genome editing, and their application in plant breeding and protection - Ethical questions related to plant breeding and protection and breeders' rights - Bioinformatics and –omics data for plant breeding and protection	
Sustainable Plant Production – from Molecular to Field Scale	The course offers a synthesis and further deepening of the basic principles of sustainable production in agriculture, horticulture, and forestry. The factors and processes that affect the sustainability and multifunctionality of production systems are integrated, by considering the different scales from the molecular to the stand level. The course also provides knowledge of the associated relevant methodologies. The course presents a review of the relevant theoretical basis and a set of specific examples relative to selected plants and production systems. On completion of the course, the student will be able to: - describe the origin of cultivated plants, the basic breeding strategies for them, and their molecular and physiological features relevant for production - discuss the effects of plant features and growing conditions on the production, yield and resource use efficiency of cultivated plants - evaluate the impacts of different management solutions on the production and yield of cultivated plants, with reference to different criteria for sustainability and multifunctionality - plan and execute the research activities necessary to answer specific research questions in the subject area, under limited guidance - present the results of these research activities in a scientifically-appropriate way	15
Swedish as a foreign language	The topics range from introducing and telling about oneself to greetings, family, food, shopping, weather and telling the time. The topics also include daily activities, living, transport and the immediate surroundings. The aim is to introduce students not only to the basic structures of Swedish, but also to the Swedish way life. Simple everyday conversation is practised.	Certificate
Spanish as a foreign language	This language course is targeted at students who chose UPV as Y2 destination and who still need to bring their Spanish to a B2 level for everyday life and professional situations. Students will learn Spanish at the rate of 2 hours per week. In addition to classroom instruction, students will realize interactive assignments. This course is carried out in close collaboration with UPV so as to ensure that the students obtain the language level needed.	Certificate

Semester 1 SZIU

SEMESTER 1 SZIU (30 credits)	Objectives	ECTS
Introductory R	This course is a general introduction to R with emphasis on tools used for data analysis. R has become the lingua franca in data analysis. However, R itself is a programming language and the learning curve can be steep. This course aims to help students with their very first steps with R: data import, subsetting, ggplot2 graphic system, other basic functions. For students with limited or no programming background. Socrative is used for participant feedback and checking comprehension.	3
Plant reproduction and reproduction biology	During the course students will be familiarized with the different reproductive organs of plants and will also gain experience in the field of *in vitro* tissue culture of gametophytic tissues and different developmental stages of embryos	3
Applied genetics	The subject applies the professional vocabulary of communication in the field of genetics; discusses the problems of Genetics plant breeding purposes. Students will acquire the basic laws of classical genetics; learn to interpret the molecular genetic background of the dominance in the case of the round and wrinkled pea phenotype. Students will get acquainted with the basics of the population genetics and interpretation of the Mendelian rules-based population genetics. They learn the genetic bases of gametogenesis and the sexual and asexual reproduction	4
Molecular genetics	After completing their studies students are able to understand and interpret the adequate theoretical problems and the most important methodological approaches in molecular genetics. The course focuses on the following topics: experiments leading to the discovery of DNA as genetic material. Functions of DNA: replication, recombination, mutation; transcription in prokaryotes and eukaryotes. Concept of gene, structure of genes in prokaryotes and eukaryotes. Classes of eukaryotic nuclear DNA, genome components; C- K- and N-value paradoxes. Biochemical, physico-chemical, molecular analysis of DNA. Bases of in vitro recombination: vectors, gene cloning, identification and selection of bacterial colonies harbouring recombinant plasmids. Characteristics of genetic regulation in prokaryotes and eukaryotes; antisense RNA technique, RNA interference. Introduces the „classical" epigenetic phenomena and their molecular background and the role epigenetics in regulation of gene expression.	4
Plant physiology and stress biology	The students will have the capability of recognizing professional problems, of their versatile, interdisciplinary approach and of exploring and formulating a detailed conceptual and practical background for solving them. The course material concentrates both on classical aspects of plant physiology and on plant ecophysiology. Emphasis is given to understanding and application of simple simulation models, utilizing basic physical and plant physiological principles during lectures and practices.	3
Microbiology and microbial biotechnology	Students participating in the course should know the basic biotechnological regularities and can apply this knowledge. Practical skills – able to execute safely a series of experiments. Use laboratory and field–based methods to generate data. Prepare technical reports; The course covers the following topics: introduction to the main classes of microorganisms – their physiology, morphology and genetics; role and activity of microorganisms in the biosphere; microbial growth and reproduction; metabolites of microorganisms and their function; role of microorganisms in the soil, animal production, crop production and environmental	5

Basics of plant breeding	Students will learn the basic theory of plant breeding and practical methods, as well. This course covers all theoretical and practical methods that are necessary for managing a professional breeding programme for autogamous and allogamous plant species. It includes both basic and more complex breeding and selection methods. Also, new technological developments and their application in breeding programmes are part of the curriculum.	3
Hungarian studies I. (Language and culture)	The course helps the students to adapt themselves to the Hungarian society by providing a basic language and cultural introduction	2
Spanish as a foreign language	This language course is targeted at students who chose UPV as Y2 destination and who still need to bring their Spanish to a B2 level for everyday life and professional situations.	Certificate

Semester 2 SZIU

SEMESTER 2 SZIU (30 credits)	Objectives	ECTS
Molecular biology and gene technology methodology	After completing the course, the students will get acquainted with the frequently used methods of molecular biology and gene technology, will have the capability to keep up with the challenges of the rapidly developing methodology of molecular genetics and recombinant DNA techniques; to word and give appropriate answers to the new problems. This course provides the basic theoretical and practical knowledge of the most important methods used in molecular biology and gene technology. Lectures and laboratory practices introduce techniques for gene isolation and cloning, types of vectors for genetic transformation, methods for transformation (direct and indirect e.g. *Agrobacterium* mediated and biolistic), the most important PCR applications, SNP detection methods, *in situ* hybridization. The lectures also deal with the types and application possibilities of reporter gene systems and procedures of gene expression analysis. The courses give opportunity for the students to try, use and practice the learned methods in the laboratory, as well.	4
Plant variety, seed testing and certification	This course covers all theoretical and practical knowledge concerning the plant variety testing and certification, the regulation and management of seed propagation, quality control and marketing. The regulations and procedures of the different countries are compared. This course provides students a Historical overview of the evolution of variety and seed certification. The course presents the legal regulation of plant variety registration, certification and protection. The test methods for plant varieties (DUS, VCU) will be presented. All requirement of seed production, the sealing, sampling seed lots, seed testing methods and also the conditions of seed certification, distribution, processing will be discussed. In the practice the students will have the opportunity to visit the plant variety and seed certifying institute. They also have the opportunity to get practice in seed tests (purity, germination, thousand seed/kernel weight, etc.).	4

Functional and structural plant genomics	The students will understand the scientific questions of plant genome analysis, will have the capability to comprehend and word appropriate answers to the new problems; reading and writing publications about plant molecular genetics-related papers. The course deals with the structure and function of gene and genome of higher plants, the characteristics of the nuclear, mitochondrial and chloroplast genomes. It introduces the levels and elements of genetic regulation of gene expression in plants. Students will get acquainted with the methods of gene identification and functional characterization. Both transformation and non-transformation-based procedures are covered (T-DNA mutants, transposon tagging, antisense RNA and RNAi techniques, TILLING, Deleteagene). As case studies the experimental approaches aiming at the clarification of the molecular background of the seven Mendelian pea traits are discussed. Genetic mechanism of male sterility, autoincompability and heterosis is also analyzed.	4
Experimental design and evaluation	After getting acquainted with the fundamental principles of experimental design and evaluation the students will be able to set up their own trials targeting plant breeding objectives. The course introduces the basic theory and methodology of field and laboratory experimentation related to plant breeding; delineates the types of the experiments and the rules of the experimental design and its realization, the methods of data evaluation.; describes the interpretation possibilities of the results, correction of the experimental errors and touches ethical issues.	3
Explorative analysis and data visualization in R	By the end of the course will be able to present and explain some visualization techniques with R script. This course aims to improve the students' data visualization skills, produce a lot of graphs feasible for thesis / conference talk / poster, explore new plotting techniques and practice R coding. For students with basic R knowledge.	3
Cell and tissue culture methodology	After completing the course, students are able to perform sterile *in vitro* work and to apply the different methods of biotechnology in practice. *Cell and tissue culture methodology* course focuses on the latest available scientific knowledge on: the principle of plant biotechnology; nutrition medium and surface sterilization; types of *in vitro* cultures; somaclonal variations; haploid and doubled haploid techniques; protoplast isolation and fusion; in *vitro mutant* isolation; secondary products from cultured cells and organs.	5
Scientific literature in English	The course comprises studies in basic classical and molecular genetics, recombinant DNA technologies, specific areas of plant and animal biotechnology and breeding. The different topics will be discussed in English with special emphasis placed on technical vocabulary and expressions in both written and spoken English. One of the most important objectives of the course is to give the students ample opportunity to practice their English in informal discussions as well as in formal presentations. It is hoped that the course will enable students to acquire fluency and confidence in the use of the language in professional conversations as well as in delivering lectures. The course also aims to allow students to read technical texts efficiently and to write scientific articles.	3
Internship	Students have the chance to get acquainted with the breeding objectives of the different companies, institutions and participate in the actual season–related breeding activities in July for 4 weeks after the field camp. In their reports they are required to introduce the company including their main breeding programs and describe the work in which they participated.	Certificate

Hungarian studies II. (Language and culture)	The course helps the students to adapt themselves to the Hungarian society by providing a basic language and cultural introduction	Certificate
Spanish as a foreign language	This language course is targeted at students who chose UPV as Y2 destination and who still need to bring their Spanish to a B2 level for everyday life and professional situations.	Certificate

YEAR 2

Semester 3 ULS

SEMESTER 3 ULS (30 credits)	Objectives	ECTS
Internship	The student will have to mature his reflection on his professional project, and confirm his professional trajectory, in particular, by direct exchanges with professionals of the chosen sector of activity and function. On this basis, he will choose a company in which he wishes to do his internship and will carry out his external diagnosis. Once in the company, he will have to familiarize himself with the problem of the internship, demonstrate an aptitude for professional practice, assert his skills and develop personally and professionally.	5
Modelling	Being able to run a simulation with a crop model and understand the architecture of a crop model and the different tools and accessories available. At the end of the module you will be able: · to create a weather database, a soil profile, an experiment, · to enter experimental data, · to run a simple simulation, · to modify genetic coefficients, · to run a seasonal analysis.	2
Statistics	Develop knowledge on data distribution, estimation procedures and confidence by examining the area of interval estimation. Acquire the tools to identify the appropriate statistical test to use regarding a scientific question. Perform a variety of univariate and multivariate analyses using R software (coding, data visualization, interpretation). Being able to mobilize skills in various context of data analysis.	3

Breeding Strategies	To be able to define the breeding goals in the midterm and long term, reasoning the breeding strategy adapted to the objectives, species, germplasm, traits to be selected according to the dimension of the breeding program, breeding tools and selection methods.	3
Seeds contracts, marketing & logistics	To be able to understand and stablish seed production contracts. To be able to secure seed supply To be able to anticipate population needs To be able to define marketing strategies upstream and downstream	2
Plant Biology & Biotechnology	The course will provide students with cutting-edge research-based training in plant biology, sciences, molecular biology and biotechnologies, as well as the integration of these disciplines in breeding programs. The teaching consists of the most up-to-date scientific advances in plant molecular biology including genetics, molecular markers, plant cell, plant development, plant physiology and plant metabolism.	6
High throughput phenotyping	To be able to choose captors in order to phenotype in field and greenhouses for the desired trait To understand the need of big data for treat the information and relation with the breeding program. To be able to treat the collected information	1
Philosophy of science	This course aims to introduce students to philosophical concepts and debates that arise in the attempt to identify, justify, and explain the distinctive features of scientific practice and discourse. In this course students will develop skills to identify, criticize and justify scientific methods. They will learn how to explain and justify scientists' choices between various research methods, and how to interpret research results. Along the way, we will also survey key issues that arise in the philosophical study of a particular science, such as biology in general, and plant breeding in particular.	2
French as a foreign language	This language course aims at providing students with the necessary language tools to interact successfully in everyday life and in basic professional situations. The objective is that students get the B1 level in French at the end of the year in order to be able to get the Engineers Diploma.	Certificate

Semester 4 ULS

SEMESTER 4 ULS (30 credits)	Objectives	ECTS
Master thesis	Held at ULS labs and fields	30

French as a Foreign language	This language course aims at providing students with the necessary language tools to interact successfully in everyday life and in basic professional situations. The objective is that students get the B1 level in French at the end of the year in order to be able to get the Engineers Diploma.	Certificate

Semester 3 BOKU – Compulsory courses

SEMESTER 3 BOKU (30 credits)	Objectives	ECTS
Molecular plant breeding	Structural genomics and functional genomics; molecular markers/fingerprinting tools: examples of techniques and methods; genetic mapping; transgenic plants; genome editing; mutations and genetic analysis, genome sequencing; QTL mapping, association mapping; marker assisted selection (MAS) and genomic selection (GS)	3
Molecular plant breeding practical	One-week lab training on: Gene transfer methods using model and crop plants (use of a fluorescent marker protein for subcellular localization; Fluorescence microscopy; Antibody extraction and purification from tobacco leaves. DNA marker applications: DNA extraction; microsatellite markers (SSR); KASP SNP-markers; mutant discovery (TILLING)	4
Master seminar	Presentation, discussion and supervision of the master thesis projects. The presentation of the master thesis (interim reports, preliminary final reports) will be held at the institute level in the context of regular events (e.g. lab-meetings, tutorials etc.).	2
Plant breeding - principles and methods	Diversity and mutations in the plant kingdom; propagation systems in the plant kingdom; genes and alleles in populations; genotypes and environments; breeder's selection for single and multiple traits, optimizing breeding selection gain; maintaining and utilizing genetic resources; needs of a plant breeder; breeding in different parts if the world, participatory breeding vs. expert breeding.	3
Plant breeding - principles and methods - practical exercises	Practical exercises on: mendelian inheritance; selection methods - inheritance and segregation of traits; Hardy-Weinberg equilibrium; phenotype vs. genotype; heritability; test crosses and combining ability; genotype by environment interaction; stability parameters; marker – trait associations.	3

Semester 3 BOKU – Electives

SEMESTER 3 BOKU (30 credits)	Objectives	ECTS
Experimental design and analysis of field and laboratory trials[1]	Work routinely with the R statistical environment (regression analysis, t-test, analysis of variance), perform analysis and understand the results of randomized complete block design (prelude to random blocks), incomplete block designs (augmented designs, α designs, p-rep, row-column designs), multi-factorial trial designs (genotype x environment interaction, split-plot designs, strip-plot designs). Optimization of trial designs (variance components, A-optimality, randomization theory)	3
Quantitative Genetics for Plant Breeders[2]	Quantitative genetic models, estimation of quantitative genetic parameters, (effects and variances), covariance among relatives, breeding values, combining phenotypes and genotypes, linear models, BLUPs, BLUES, genome wide prediction and selection.	3
Resistance breeding of crop plants (in Eng.)	Active student participation through student presentations; concepts, terms and definitions in relation to resistance breeding; examples for resistance to facultative pathogens; examples for resistance to obligate pathogens; methods and approaches for the identification of resistance genes; strategies and options for resistance breeding	3
Molecular mechanisms of fungal virulence and plant resistance	Effector proteins of fungi and oomycetes and their role in virulence; role of fungal secondary metabolites and their mode of action in plants; defense mechanisms in plants, signal transduction and role of induced proteins; Chemical inactivation of fungal metabolites by plant enzymes; novel approaches in fungal and plant genomics and metabolomics	3
Gene technology for plant pathologists	Use of transgenic plants to improve resistance of plants against pathogens and pests; discussion of the advantages and possible risks of using transgenic plants in agricultural systems.	3
Molecular evolution and phylogenetics	Analysis of high-density sequence data for measuring phylogeny, to assess evolutionary trends, and to study the changes within genomes over time. The lecture will provide insight into the molecular principles underlying the evolution of DNA, proteins and genomes. Different ways how to perform phylogenetic analyses will be discussed. Bioinformatics methods to study molecular evolution will be presented.	1

[1] Highly recommended for students who studied their first year at ULS or at SLU
[2] Highly recommended for students who studied their first year at SZIU or at SLU

Global change and pest management	Climate change – basics, changes in atmospheric CO2, climate scenarios; effects of changes in atmospheric gases, temperature and precipitation on host plants, pests and their interactions; effects of climate change on natural enemies; effects of land use change on population dynamics of pest arthropods and biological control by natural enemies; neobiota as invasive pests – pathways, risk, approaches for control; effects of climate change on invasive pest species.	3
Plant metabolomics	Fundamentals of modern metabolomics research. The general concept will be illustrated with a practical example study on the metabolism of wheat. The lecture part will cover the basic principles of metabolism and the involved methodology. The practical section will be held in small student groups. You will carry out a complete metabolomics experiment involving plant treatments, sampling and sample preparation, PLC and mass spectrometry, data evaluation; biological interpretation of results	5
Aspects of product quality in plant production	Criteria of crop product quality; Crop composition (proteins, oils, carbohydrates, fibers, vitamins, toxic components etc.); analytical methods for crop quality determination; breeding for quality characters in selected crop species; environmental implications of crop quality; agronomy and quality; Practical tool: introduction to near-infrared reflectance spectroscopy; breadmaking quality testing; rapid screening methods; molecular genetic methods of quality analysis (protein- and DNA-markers)	4
Bioinformatics lab rotation	Getting to know bioinformatics research is essential for students who wish to perform their master's thesis in a computational lab. This course gives an overview of the research directions in BOKU bioinformatics groups, and students will “rotate” through three labs. The participating faculty present their work in lectures based on which each student will select labs for carrying out a project. Each project comprises 16 hours of work, consisting of 90% practical work on the computer and 10% report writing. The rotation projects give the opportunity to get a first impression of the actual work in a particular lab and will provide an orientation to the students in which group to conduct their master thesis.	2
Genetics of diversity	Introduction to biodiversity; measuring genetic diversity; genetic variation and population size; genetic variation and population size – selection, migration, drift; effective population size; population subdivision; relatedness and inbreeding; inbreeding and inbreeding depression; pedigree measures of diversity; units of conservation-phylogenetic relationships; Conservation strategies in farm animal genetic resources; evaluation of genetic diversity using genomic data	3
Quantitative animal genetics	Simple genetic models (1- and 2-locus); estimation of heritability and genetic correlation in animal population; BLUP estimation of breeding values; QTL - genes of large effect; marker assisted and genome wide selection	6
Free elective	Any course from BOKU university – such as “German as a foreign language”	3

Semester 4 BOKU

SEMESTER 4 (30 credits)	Objectives	ECTS
Master thesis	Master thesis should help to have a deep knowledge in plant breeding either in fundamental or applied research in a university, research center or seed company or seed related institutions. It will help to deeper the knowledge of methods in plant breeding. Students will contribute to research and development work. Students will have to develop a critical, independent and creative identity in order to formulate and deal with complex issues, evaluate different technical solutions and be able to make a critic and integrate systematically the knowledge. They will have to be able to plan and use adequate methods to conduct qualified tasks in plant breeding. At the end they will have to clearly present and discuss the conclusions as well as the knowledge and arguments that form the basis for these findings in written and spoken English.	30

Semester 3 UMIL

SEMESTER 3 UMIL (30 credits)	Objectives	ECTS
Molecular methods for plant breeding	The course provides in-depth elements of plant breeding, referring to the use of techniques of biometrics, molecular biology, genomics, functional genomics and genetic engineering. The first part of the course provides a review of the concepts of Mendelian genetics aimed to understand the application of molecular markers in mapping studies of genomes and identification and cloning of the chromosomal regions responsible for simple and quantitative characters (QTL). The theme of molecular markers is addressed with their applications to both mapping and fingerprinting of genomes. The concept of marker-assisted selection (MAS) is developed accordingly. The second part deals with the theme of next-generation sequencing (NGS) and large-scale analysis of genomes with applications like Genotyping by Sequencing (GBS), Genome-Wide Association Studies (GWAS) and Genomic Selection (GS). The third part of the course is devoted to the study of gene expression, starting with the simplest cases up to large-scale applications, which are addressed by the most recent technologies (i.e. RNA-seq and variations). Bioinformatic methods of data analysis and access to major biological databases with simulations in the classroom are also addressed. The fourth part of the course will outline the production and use of transgenic plants for applications aimed at the improvement of agronomic and technological traits. Important and integral elements of the course consist of exercises in the classroom and in the laboratory that allow the student to practice more in depth and better understand the concepts exposed in the lectures.	6

Plant molecular biology	Objective of the course is to provide students with knowledge of molecular biology concepts and experimental approaches to understand gene function in plants, also through the analysis of case studies in crops The student will become familiar with the approaches used to investigate the fundamental link between gene structure, function and phenotype. Competences will also include the analysis of gene sequence and expression as well as allelic variations.	6
Crop modeling	**Training objectives** · Teach the basic principles of agronomic process simulation, and the methods to adapt agronomic models at different crops, soils and climates. · Favour learning of a process-based quantitative approach to analyze the interactions crop x environment x management. · Provide examples of model calibration, validation and sensitivity analysis using case studies. **Expected learning outcomes** Know and understand: · principles of cropping system models; · ways to simulate crop development and growth; · ways to simulate crop response to some abiotic and biotic stresses; · model calibration, validation and sensitivity analysis. Be able to: · implement simple crop development and growth models; · apply these models at different climatic conditions (present and future); · carry out calibration, validation and sensitivity analysis.	6
Basic statistics and experimental design	Overview on descriptive statistics, sampling distribution and statistical test: Basic of descriptive statistics: central tendency and dispersion indices. Characteristics of samples and populations. Main probability distribution. Usage of the normal distribution and of the standardized normal distribution. Estimation of population parameters from a sample. Bias, consistency and efficiency of an estimator. The structure of a statistical test: two-tail and one tail-test, the null hypothesis, the significance level, power of a test, type I, II and III errors. Practical use of statistical software to do descriptive data analysis and ANOVA (2- 3 way). Experimental planning and field management of the experiments. Uncontrolled sources of error and the determination of the number of replications. Randomized blocks, Latin squares, split plot and strip plot experimental arrangement. Practical implementing in a field of experimental arrangement. Practical use of statistical software to analyze field experiments carried out under different experimental schemes	6
Plant Breeding	Essentials of Genetics: Quantitative genetics and Population genetics. Chromosome and gene mutations. Plant propagations: allogamy, autogamy and vegetative propagation. Genetic constitution of the main crops: natural populations, ecotypes, synthetic populations, clones, inbreed lines, hybrids. Essential of genetics improvement in plant breeding: recurrent selection, inbred line extraction, backcrossing, hybrid varieties and mutagenesis. The "green revolution" and its genetic basis. New tools: marker assisted selection (MAS) and genetically modified plants (GM crops): resistance to pests and herbicides and other examples. Next Generation Sequencing and Genome editing.	6

Development of crop ideotypes	Objective of the course is to provide students with knowledge of multidisciplinary approaches to design and breed new crop ideotypes to improve quantity, quality, efficiency and sustainability of agricultural production for different end-uses. Integrating genetics, genomics and modeling, the course is centered on ideotype breeding with special focus on cereals and other cultivated plants as case studies.	6
Italian as a foreign language	Italian courses will cover the grammar rules, reading, and comprehension. The programme will be adjusted according to the level attained at the entry-level test (placement test). Students will attend one of the required courses. A1 from C1 60-hour courses are held each semester. Students who attend at least the 66% of in-person learning can take the end of course test and receive a language certificate and a certificate of attendance. Students from International Medical School have access to 80-hour annual courses to attain A1/A2, B1 and B2 levels.	Certificate

Semester 4 UMIL

SEMESTER 4 (30 credits)	Objectives	ECTS
Master thesis	Master thesis should help to have a deep knowledge in plant breeding either in fundamental or applied research in a university, research center or seed company or seed related institutions. It will help to deeper the knowledge of methods in plant breeding. Students will contribute to research and development work. Students will have to develop a critical, independent and creative identity in order to formulate and deal with complex issues, evaluate different technical solutions and be able to make a critic and integrate systematically the knowledge. They will have to be able to plan and use adequate methods to conduct qualified tasks in plant breeding. At the end they will have to clearly present and discuss the conclusions as well as the knowledge and arguments that form the basis for these findings in written and spoken English.	30

Semester 3 UPV

SEMESTER 3 UPV (30 credits)	Objectives	ECTS
Plant Breeding for resistance to stresses	Description: During the lectures breeding methods and special cases related to: i) viruses, ii) fungi, iii) bacteria, iv) pests and v) abiotic stresses (salt, drought, flooding, low-input conditions, low or high temperatures, etc.) are addressed Contents: Models of host-pathogen interaction. Mechanisms of resistance. Resistance genetics. Durability. Specific strategies and methods for improvement. Programs of improvement according to the source of variation (host, pathogen and others). Economic impact of abiotic stress alterations	5

	Physiological effects produced by different types of abiotic stresses. Resistance to water stress. Resistance To saline stress. Resistance to low temperatures. Resistance to high temperatures. Development of Parthenocarpic cultivars. Improvement to other types of stress. Learning outcomes: 1. Use knowledge in plant pathogen interactions and genetics in breeding programmes for plant resistance to pest and diseases. 2. Use knowledge in plant physiology and genetics in breeding programmes for plant resistance to abiotic stresses. 3. Locate, analyse, evaluate and synthesise information relevant to plant breeding for resistance to biotic an abiotic stresses. 4. Communicate conclusions, and reasons that support them, to specialized and non-specialized audiences in a clear and unambiguous way 5. Judge which plant breeding methods are appropriate for introducing resistance to plant varieties. 6. Carry out specific phenotyping activities within the resistance breeding (inoculations, stress experiments, stress response measurements…) 7. Use biotechnology advances in breeding for resistance Methods: The course will be delivered by the following means: Lectures (using flip teaching methods), case studies, Practical lab sessions, and home work. The assessment will be continuous.	
Breeding for crop quality	Description: Factors involved in the quality of edible plant products and their breeding are studied. Bioactive compounds, cereals´ quality, sugars and acids, organoleptic quality, quality for industry traits (oil yield, fatty acids profile) etc. Contents: Concept of Quality. Components of quality. Organoleptic and nutritional quality. Difficulties in quality breeding. Analytical quality assessment. Genetic regulation of quality. Influence of the environment on the parameters of quality. Mathematical methods and techniques of analysis. Specific improvement for different crops. Learning outcomes: 1. Use knowledge in metabolic pathways and genetics in breeding programmes aimed at increase the nutritional/organoleptic/taste quality of the plants 2. Locate, analyze, evaluate and synthesize information relevant to quality plant breeding 3. Communicate conclusions regarding quality breeding, and reasons that support them, to specialized and non-specialized audiences in a clear and unambiguous way 4. Judge which plant breeding methods are appropriate for improving the plant internal quality. 5. Carry out metabolites analysis (sugars, polyphenols, vitamins, etc) 6. Use biotechnological tools in breeding for quality Methods: The course will be delivered by the following means: Lectures (using flip teaching methods), case studies, practical lab sessions, and home work. The assessment will be continuous.	5

Fruit (Tree) species breeding	Description: Review of the specific traits, limitations and factors related to tree (fruit) species. Current genomic and genetic tools applied to their breeding. With particular emphasis on the most common ones in Spain: stone fruits a pip fruits, almond and olive trees, loquat, persimmon, and some shrubs. Contents: Methods of improvement in the short, medium and long term. Cloning in the selection and propagation. Design of mating and selection methods. Methods of improvement based on Hybridization and clonal selection. Selection of patterns and grafts. Biotechnology methods in improvement Of tree species. Genetic improvement of forest conservation. Learning outcomes: 1. Describe methods that are used in tree breeding 2. Use jointly conventional breeding methods and new biotechnologies to improve tree species 3. Use of plant genetic resources in breeding programs. 4. Carry out specific breeding activities, such as selection of parental germplasm, observation and recording of phenotypic variation and selection among progeny Methods: The course will be delivered by the following means: Lectures (using flip teaching methods), case studies, practical lab sessions, and home work. The assessment will be continuous.	5
Ornamental Plants Breeding	Description: Breeding procedures and examples of the most relevant ornamental species: roses, carnation, tulips, lily, cactaceae, etc. Contents: Specific breeding objectives. Generation of variation in ornamentals: intra and Interspecific, mutagenesis, somaclonal variation and others. Clonal propagation. Micropropagation. Methods of improvement. Learning outcomes: 1. Describe methods that are used in ornamental breeding 2. Use jointly conventional breeding methods and new biotechnologies to improve ornamental species 3. Use of plant genetic resources in breeding programs. 4. Carry out specific breeding activities, such as selection of parental germplasm, observation and recording of phenotypic variation and selection among progeny. 5. Formulate and justify a plan for the application of plant breeding methods to achieve a specific objective. Methods: The course will be delivered by the following means: Lectures, practical lab sessions, and homework. The assessment will be continuous.	5
Transgenic Plants	Description: Using transgenic technology, the agricultural, horticultural or ornamental value of plants can be improved quickly and precisely. This technology represents a strategic bet for the future to promote research and innovation in key productive sectors for economic and social development, such as the agri-food and biotechnology sectors. The objectives of the course will consist of learning the different phases of a genetic transformation program and the techniques used in each of them. The basic requirements for the transformation of plants, the main improvement objectives and the different techniques that allow the analysis and detection of transgenic plants will be analyzed. Other	4

	important objectives of the subject are those that refer to the benefits and possible risks of the use, cultivation and experimentation with transgenic plants, as well as with regard to legislation. Contents: - Basic requirements and methods for obtaining transgenic plants - Genetic transformation via a*grobacterium*. Stages of transformation. The plasmid Ti. Vectors derived from the Ti plasmid. Transformation methods with A. tumefaciens. The plasmid Ri. Transformation with A. rhizogenes - Genetic transformation by means of biolistic methods. System Components. Stages. Plants transformed via bombardment. Chloroplast transformation. Other transformation methods - Elimination of marker genes in transgenic plants. Co-transformation. Removal of the marker gene by transposable elements. Systems based on microbial recombinases. Intrachromosomal recombination - Other methods. Agroinfiltration. Transient transformations based on viral vectors - Genetic silencing. Transcriptional gene silencing. Posttranscriptional gene silencing. miRNAs and tasiRNAs - Gene editing. Genome editing with site-specific nucleases (zinc finger and TALENS). The CRISPR / Cas system. Prime editing. Applications of genome editing in plants - Methods for detecting transgenic plants - Applications - Safety and risks assessments and legislation in force. Learning outcomes: - Describe transformation methods used for plant breeding - Formulate and justify a plan for the application of transgenesis in a breeding programme - Use of in vitro culture techniques in plant breeding - Judge the risk of using transgenic plants for human health and the environment - Describe the legal regulations on transgenic plants Methods: The course will be delivered by the following means: Lectures, practical lab sessions, and homework. The assessment will be continuous	
Advanced Plant Breeding methods	Description: This course is aimed to show and develop the different selection systems applicable to cultivated species, according to their reproductive system and the type of population to be obtained. In addition, during the course the students evaluate the advantages and disadvantages of each selection method, as well as the genetic advance that can be achieved with them. All using the new molecular tools available and statistical methods. Content: Setting goals for breeding. Most important current objectives and breeding methods in extensive and intensive self-pollinated (wheat and tomato) Most important current objectives and breeding methods and alogamous crops (corn and melon). Plant genetic resources and sources of variation. Introduction and management of the necessary genetic variation. Molecular markers and genomic tools Handling and selection of materials during the improvement program.	5

	Evaluation and comparative tests. Learning outcomes: - Use the appropriate plant breeding strategy depending on the biology of the plant - Use of conventional and biotechnological selection and breeding techniques. - Analysis of genetic gain and predict results of selection. Methods: The course will be delivered by the following means: Lectures, practical lab sessions, and home work. The assessment will be continuous.	

Semester 4 UPV

SEMESTER 4 (30 credits)	Objectives	ECTS
Master thesis	Master thesis should help to have a deep knowledge in plant breeding either in fundamental or applied research in a university, research center or seed company or seed related institutions. It will help to deeper the knowledge of methods in plant breeding. Students will contribute to research and development work. Students will have to develop a critical, independent and creative identity in order to formulate and deal with complex issues, evaluate different technical solutions and be able to make a critic and integrate systematically the knowledge. They will have to be able to plan and use adequate methods to conduct qualified tasks in plant breeding. At the end they will have to clearly present and discuss the conclusions as well as the knowledge and arguments that form the basis for these findings in written and spoken English.	30