Plant Systems Interactions with the Environment for Sustainable Agroecology (PLANT WISE)

Explore this IDIL Master's track in detail, including its academic objectives, curriculum, research opportunities, admission requirements and career prospects.

TRACK OVERVIEW & LEARNING OBJECTIVES

Like all tracks in the IDIL international master's program—which is taught entirely in English—the PLANT WISE track is characterized by intensive "laboratory-based" instruction, with immersion in research beginning in the first year of the master's program:

- The "Personal Project," developed with a mentor and an academic advisor, as well as the "InLab" sessions—experimental workshops in the laboratory—facilitate the acquisition of complementary skills and cutting-edge techniques.
- Internships last 6 months, during the second semester of both the first and second years of the master's program.
- Intellectual openness and a personalized academic path are fostered by a wide selection of "non-core" and "interdisciplinary" courses, as well as by the summer school.

The PLANT WISE program teaches a very broad and up-to-date range of concepts and tools that can be applied to high-level research projects in plant physiology and agro-environmental sciences.

For the past 80 years, agricultural production has followed an approach centered on maximum productivity, the artificial enhancement of soil fertility, and globalized supply chains for inputs and product distribution. This strategy has largely succeeded in ensuring food security—both in terms of quantity and quality—on a global scale. However, rapid ecological and geopolitical changes are now revealing its limitations. Indeed, climate change and pressures on critical resources (fertilizers, energy, water and land)—against the backdrop of a continuously growing global population over the next five decades—are causing increasing uncertainties. Negative externalities, such as pollution and ecocidal pressure, further underscore the urgency of a new, more robust, and sustainable form of development.

Alternatives labeled as agroecological redefine the cultivated field as an agroecosystem, in which biological complexity is reintroduced, maintained, and channeled. The cultivated plant interacts with multiple organisms, from the molecular to the landscape scale: fertility stems from living soil, and plant health arises from symbiotic relationships and ecosystem balances. From this perspective, the development of new agronomic solutions—along with the associated environmental management—requires a thorough understanding of the mechanisms of plant nutrition, defense, and the complex ecophysiological interactions that promote crop production. This opens-up broad avenues for upstream fundamental research, as the former director of the FAO stated in 2018: "The future of agriculture is not input-intensive, but knowledge-intensive. We need the integrated approach that agroecology can offer."

At the heart of this new paradigm, the PLANT WISE international master's program offers a unique curriculum covering the study of plant nutrition, defense, and genetics in response to positive and negative environmental stimuli. The course integrates state-of-the-art knowledge in functional biology, as well as the most advanced methodological approaches in the fields of cellular and molecular biology, microscopy, genomics, and metabolomics. In the first year, four teaching units cover fundamental aspects of plant adaptation to their environment:

- Local and systemic cellular signaling pathways
- The molecular basis of cell differentiation and organogenesis
- The role of specialized metabolites in plant-environment interactions and their potential applications
- Mechanisms of trophic, mutualistic, and pathogenic interactions between plants and its microbiome.

In the second year, students will have the opportunity to tailor their program by choosing 3 courses from a selection of 5, allowing them to focus their studies on

- Genomic bioanalysis (genome sequencing, genome structure, functional annotation) and advanced research topics on plant diversity and adaptation.
- Ecophysiology and plant-microorganism interactions, particularly molecular interactions in complex environments.
- Developmental and metabolic plasticity in response to nutrients and abiotic stress.

KNOWLEDGE, SKILLS & COMPETENCIES

Plant functionnal biology

- Understand how the integration of endogenous and environmental signals, regulatory networks and cellular processes enables the continuous production of functional tissues and organs and shapes the plant architecture in interaction with its environment.

- Understand signaling mechanisms involved in plant responses to major environmental stresses (drought, nutrient deficiency, salinity, temperature, etc.): the molecular components of these responses, the successive events in cellular or systemic signaling, and the interactions between signaling pathways.

- Understand the principles of plant ecophysiology through a case study, by analyzing the effects of temperature and energy balance on plant development, growth, transpiration, and yield using a multiscale approach—from the cellular level to the plant canopy—and apply these concepts to the adaptation of crop management practices and breeding.

- Assess the physicochemical and biological properties of the major classes of metabolites and their ecophysiological functions. Recognize and interpret metabolite structures and identify and quantify metabolites as part of a functional analysis.

- Explore a range of “omics” applications that reveal the structure and evolution of genomes, as well as their expression and adaptation.

- Use of modeling in plant breeding, such as structure-function modeling tool (OpenSimRoot), to propose a root architecture ideotype adapted to specific edaphic conditions

- Work with various plant models and master the rationale behind translational research, aimed at transferring the highly characterized molecular mechanisms in Arabidopsis to crop plants, including important crops from temperate, tropical and Mediterranean regions.

Data sciences

- Access, use, and analyze various types of omics data (e.g., (epi)genomic, transcriptomic, proteomic, metabolic) to accelerate research in functional genomics and plant biotechnology.

- Select and effectively conduct an analysis of data derived from the latest sequencing technologies, which may reveal genetic factors of adaptation relevant to traits of biotechnological or agronomic interest.

- Master the access, use, and analysis of comparative and pan-genomic data using state-of-the-art bioinformatics platforms (high-capacity computing and storage centers, FAIR data: Findable, Accessible, Interoperable, Reusable) to elucidate how plant genomes evolve and are expressed.

- Combine ecophysiology, High-throughput phenotyping, envirotyping, and modeling to analyze Genotype × Environment × Management (G×E×M) interactions and link measurements acquired at different scales to the integrated functioning of plants and vegetation.

- Design experimental setups, analyze multi-environment data, and use models to interpret genetic and phenotypic variability

- Master the tools and methods for studying metabolic pathways at the molecular and phylogenetic levels (genes, enzymes, pathways, structures, functions). Effectively manage large datasets and interrogate them using univariate and multivariate statistical analyses.

Scientific Inquiry and Experimentation

- Explore a research topic based on literature, contextualize a problem in biology or plant sciences to formulate clear research hypotheses.

- Define an experimental design that specifies the variables to be controlled and the variables to be studied, in conjunction with an appropriate statistical analysis.

- Apply knowledge to scientifically analyze specific experimental results, interpret them critically, and discuss them objectively—both in writing and orally—in an organized and independent manner, either individually or in a group.

Immersion in the Research Community

Long-term integration into a team challenges the organizational structure of a research institute and the various roles within it, from administration to research project management. It provides an opportunity to gain an understanding of the work environment in a research laboratory: managing a project over the long term,

effectively managing time and resources, and becoming familiar with the mechanisms for funding and monitoring research projects.

DETAILED CURRICULUM

- **Semester 1 (S7)**
  - HAA702V_Environmental Adaptation and Signaling (3 ECTS)
  - HBA703V_Plant functional metabolites (3 ECTS)
  - HA1I07V_Plant development and adaptation (3 ECTS)
  - HBA705V_Molecular Plant Microbes Interactions (3 ECTS)
  - QAM1PPRJ_Personal project : Research project + English (10 ECTS)
  - QAM1TTRA_Transversal Unit (4 ECTS)
  - QAM1ILAB_In-Lab (2 ECTS)
  - Non Core Unit (2 ECTS)

- **Semester 2 (S8)**
  - HBA801V_Research Internship (30 ECTS)

- **Semester 3 (S9)**
  <u>Chose 3 among 5 :</u>
  - HBA916V_Comparative pangenomics (3 ECTS)
  - HBA917V_Introduction to ecophysiology (3 ECTS)
  - HAA929V_Plant mineral nutrition and adaptation to abiotic stress (3 ECTS)
  - HAA937V_Integrated project in plant breeding: phenotypes, models, ideotypes (3 ECTS)
  - HBA704V_Integrative biology of microbial interactions 1 (3 ECTS)

  - HA1I12V_Thematic schools : Phytobiome (3 ECTS)
  - QAM2MUTP_Multidisciplinary team project (10 ECTS)
  - QAM2TTRA_Transversal training unit (2 ECTS)
  - HA1I08V_Experimental approaches (InLab) (2 ECTS)
  - Non Core Unit (2 ECTS)

- **Semester 4 (S10)**
  - HBA001V_Research Internship (30 ECTS)

In-Labs :

- …IPSiM **Introduction to the functional analysis of ion channels using the patch-clamp technique on plant cell membranes**. Alexis de Angeli, Elsa Demes-Causse.

- IPSiM **Local ion concentration and flux measurements at the surface of plant roots using ion-selective microelectrodes** Martin Boeglin, Claire Corratgé-Faillie, Anne-Aliénor Véry.
- IPSiM **Imaging methods for plant abiotic stress analysis** Carine Alcon, Alexandre Martinière.
- IPSIM **Stress and microbes on plants** Philippe Nacry, Guilhem Desbrosses.
- IPSIM **Rice mycorhization** Doan Luu.
- LEPSE **Photosynthetic and stomatal responses to climate change: analysis and interpretation** Romain Boulord, Aude Coupel-Ledru.
- LEPSE **Reconstructing and analysing plant architecture from phenotyping platform images for virtual plants**. Christian Fournier.
- DIADE **Phenotyping in water stress maize** Julia Engelhorn.
- IPSiM **Introduction to metabolic phenotyping: LC-MS phytohormones profiling** Raphaël Lugan, Thibaud Perez.
- IPSIM **Exploring protein-protein interaction networks using the yeast Saccharomyces as a reporter in vivo system** Florence Vignols.

AGAP **Research mini-projects investigating adaptive introgressions in thousands of Asian rice varieties** Julien Frouin, Jean-Christophe Glaszmann, Julia Engelhorn, Stéphanie Bocs

ADMISSION REQUIREMENTS & STUDENT PROFILE

The PLANT WISE master's program is designed for students who have completed a wide variety of biology-related programs (bachelor's degrees, specialized schools, *etc.*), with a focus on physiology, ecophysiology, biochemistry, agronomy or ecology of plants.

Significant coursework in physiology and cellular / molecular biology, particularly some basic knowledge of plant physiology (development, nutrition, genetics), is strongly recommended. An interest in laboratory work, within an environment rich in technical opportunities and human interaction, is also an asset for success in this program.

The minimum required degree is a bachelor's degree or equivalent. No knowledge of French is expected but proficiency in English is required.

Important Prerequisites

- Basic knowledge of photosynthetic organisms: physiology and development; structure and general functioning of plant cells and tissues, from the cell to the organism.

- Fundamentals of molecular biology and genetics: nucleic acids and proteins, transcription and translation, mutation and evolution.
- Awareness of key biochemical functions, such as enzymatic reactions and central energetic and biosynthetic metabolism.
- Basic knowledge of computing environments related to data processing (R, RStudio, spreadsheet, etc.) and common statistical analysis techniques used in biology (analysis of variance, correlations, etc.).

Other valuable prerequisites, depending on student background (non-exhaustive)

- Basic knowledge of plant hormonal signaling, as well as sap transport and circulation among organs in a plant.
- Fundamentals of structural organic chemistry: atoms, molecules, covalent bonds, chemical functions, major classes of central metabolites (sugars, amino acids, etc.).
- Genetics, genetic association, plant population biology.
- Theoretical and practical knowledge of standard laboratory techniques (weighting, pipetting, calibrating…).

CAREER OPPORTUNITIES

The PLANT WISE master's program trains professionals for careers in basic or applied research in plant sciences. Typical career paths include research analysts and experimental project managers at technology platforms or experimental facilities, to conduct cutting-edge analyses and provide technical supervision in laboratories, to oversee scientific projects in environmental science, agronomy, or plant resource management, develop research protocols, and maintain technical platforms.

Pursuing a Ph.D. is a central goal of this program, whether at a public research institution or with a private partner. In academia, a Ph.D. leads to careers as a research fellow or assistant professor, and in the private sector, to careers in R&D and consulting.

Recruitment in academic research takes place at major research institutes, institutions of higher education like universities, technical centers, or health agencies for positions related to the environment.

Industrial sectors open to students with a PLANT WISE background include breeding and seed production, agricultural supply companies specializing in plant nutrition and protection, agricultural research stations, private environmental monitoring organizations, and biotechnology companies.

RESEARCH LABORATORIES & ACADEMIC PARTNERS

The number, diversity, and exceptional quality of the plant science research laboratories in Montpellier are undoubtedly one of the major strengths of this master's program. They have global collaboration networks spanning every continent and focus on the crops most important to global agriculture. They also are equipped with state-of-the-art platforms for biological research: cutting-edge bioinformatics tools supported by high-capacity computing and storage centers, molecular analysis, metabolomics, high-throughput phenotyping platforms, plant variety collections, microscopy, and more.

These laboratories are organized into several institutes that cover complementary areas of research:

IPSIM (Plant Sciences Institute of Montpellier): *10 research groups.*
Investigation of the fundamental molecular mechanisms governing plant water and mineral nutrition and their responses to abiotic environmental stresses, notably those related to climate change.

LEPSE (Plant Ecophysiology under Environmental Stress): *2 research groups.*
Study of plant responses to drought and high temperatures and exploration of their genetic variability. Integration into models enabling the evaluation of the performance of current and future farming practices, species, and varieties based on future climate scenarios.

DIADE (Plant diversity, adaptation and development): *7 research groups.*
Study of biodiversity, adaptation, and the development of tropical plants: adaptive mechanisms and environmental interactions that contribute to food security and the agroecological transition.

AGAP (Genetic Improvement and Adaptation of Mediterranean and Tropical Plants): *11 research groups.*
Study the mechanisms underlying plant development and adaptation to the environment. Characterize the organization and diversity of plant genomes and preserve them in large collections of genetic resources. Develop breeding methods and tools for plant variety innovation

PHIM (Plant Health Institute Montpellier): *16 research groups.*
Study of interactions between plants and their environment that affect plant health, growth, and productivity. These interactions involve microbial organisms or insects, whether pathogenic or beneficial

AMAP (botAny and Modeling of Plant Architecture and vegetation): *11 research groups.*
Acquiring fundamental knowledge about plants and vegetation to predict how ecosystems will respond to environmental drivers, in terms of species distribution and conservation, biodiversity, agricultural crop production, carbon storage in plant biomass, environmental protection, and ecosystem services.

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