Genome-wide predictions in breeding: genotype-phenotype associations and genomic selection.

Week 1: Theoretical background in breeding

Day 1. Breeding strategies – Introduction
Should cover principles and concepts of inheritance, germplasm resources, pollen control, measurement of genetic variances, and heterosis. Special topics include heritability, genotype-environment interaction, disease resistance, and polyploidy.

Day 2. Molecular biology in breeding
Theory and principles of molecular biology applied to plant breeding. Experimental approaches to induce genetic change, cytoplasmic recombination, haploid utilisation, and potentials of molecular techniques for solving breeding problems.

Day 3. Breeding for Resistance
Abiotic stress is caused by environmental factors (temperature, water, nutrients, minerals). Breeding for abiotic stress resistance and tolerance deals with concepts such as adaptability and stability, mechanisms of stress tolerance and phenotyping for selection, genotype by environment interaction and selection in multi-environment trials. Breeding for biotic stress resistance deals with defence mechanisms and strategies that protect against pests and pathogens, inheritance of resistance genes, and durable effectiveness of resistance genes. Animal breeding also deals with complications related to the mating systems of the organisms involved, making the design of breeding plans very different to crop plants. In this regard, we will talk about disentangling disease resistance from resilience and infectivity, about how gene editing is emerging as a strategy for disease control also in animals.

Day 4. Breeding for quality
Quality breeding is mainly directed at improving plant compounds like carbohydrates, proteins, vegetable fats and oils, fibres and secondary metabolites, that are all synthesized in metabolic pathways. Breeding objectives include improved product quality (e.g. taste, shelf life), enhanced production of flavours, fragrances and health-supporting components, absence of allergens and other undesirable compounds and improvement of processing characteristics of plant raw materials.

Day 5. Breeding and Biodiversity
Risks of introducing elite cultivars in centers of origin. Ethical discussion on management of genetic variation. The different philosophies of animal and plant breeding would contrast and potentially enrich each other, both when it comes to the maintenance of diversity and managing inbreeding, as well as the possibility (or not) of introgression, crossbreeding and pre-breeding.

Weeks 2 & 3: These two modules will be heavy in theory and hands-on. Students are welcome to bring their own dataset.

Week 2: Genomic selection

Day 1: Population genetics and quality control of genomic data

- Lecture: Population genetics and population structure– changes in allele and genotype frequency, linkage disequilibrium and haplotypes.
- Exercises on population genetics with Q&A.
- Project: genotype quality control.

Day 2: Introduction to GS

- Lectures: BLUPs. Fixed and random effects difference in the model. Variance components and relationship. From sire to animal model. Multiple traits.
- Exercise: Create environment for BLUP evaluations. Run BLUP on real / simulated data.

Day 3: Factors affecting Genomic Selection

- Lectures: Genotype by Environment interaction. Differences between self- and cross-pollinated crops. Training and breeding populations (size), models, heritability.
- Exercises: Contrast different models.

Day 4: Single and two step model

- Lectures: Theory of Single-step GBLUP. Forming Single-step equations. Two-step GS.
- Exercise: Run ssGBLUP on real / simulated data.

Day 5: Cross-Validations

- Lectures: Single-step for populations under selection: bias, inflation, accuracy. Validation methods. Limitations of GS.
- Forestry (to be added).
- Exercise: Validate own models and accuracies.

Week 3: GWAS

Day 1: Quantitative genetics and complex traits

- Lecture: Quantitative genetics for GWAS – genetic values and variances, biological and statistical effects
- Exercise: Phenotype quality control and modelling

Day 2: Getting started with genome-wide association studies

- Lecture: How to perform a genome-wide association study
- Exercise: Running a first GWAS

Day 3: Advanced genome-wide association studies

- Lecture: Advanced genome-wide association studies – different models, imputation, fine-mapping, variant prioritisation
- Exercise: Time to refine the GWAS and results

Days 4-5: Evaluation of the course. Presentations and discussion