PLANT SUCCESS POSTGRADUATE PROJECT CONCEPTS: QUANTITATIVE GENETICS

Experimental and mathematical exploration of the structure of trait fitness landscapes in Arabidopsis using branching mutants to perturb the exposed natural variation for branching and flowering traits.

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BACKGROUND

The objective is to develop an open access resource for advanced experimental-modelling-simulation studies through the life of the CoE Plant Success. The target model organism will be Arabidopsis.

We have acquired the 1001+ Arabidopsis set of diversity lines to be used as a foundation population (diversity panel: At_DP1001+) to study genetic and trait phenotypic variation in combination with modelling and prediction methods, focussing on the Beveridge branching network. Following initial phenotyping for branching traits, the At_DP1001+ will be used to generate multiple segregating populations to undertake a series of "selection & mapping" experiments (e.g., Wisser et al. 2019). The data generated from the "selection & mapping" experiments will be used to study the exposed genetic and phenotypic variation associated with the branching network and explore the development of prediction models to guide selection trajectories and to test the efficacy of the prediction models.

The selection trajectories that can be discovered, as the "selection & mapping" experiments progress, is constrained by the set of potential trajectories that are accessible, given the natural variation that can be generated by segregating genes that are polymorphic from combinations of individuals available within the At_DP1001+. Thus, our accessible views genome-to-phenome information for traits is conditioned by the allele states for the gene networks controlling traits within the individuals of the At_DP1001+ (Podlich and Cooper 1998). The data generated from the natural variation can be used to develop mathematical representations of trait fitness landscapes (Wright 1923, Kauffman 1993, Gavrilets 2004). It would be interesting to investigate applications of manifold theory to construct informative representations of the exposed features of the trait fitness landscapes and to explore applications of the generated views to guide selection trajectories.

While investigations of fitness landscapes and predictive modelling for the At_DP1001+ natural variation will be interesting, we have the potential to expose and explore novel trait variation using the branching network mutant genetic resources available in the Beveridge group. This could be investigated by making crosses between key branching network mutant lines and the members of the At_DP1001+. From these crosses the mutants would provide perturbations to the exposed genetic variation that can be generated using the At_DP1001+. This would open the opportunity to test whether the mutant perturbation expose new dimensions of the fitness landscapes or change the shape of the fitness landscapes. Many core CoE areas of focus could be supported by the resources generated from these experimental efforts. Further, many fundamental questions related to predictive modelling of properties of gene networks and their phenotype consequences could be investigated.

PROJECT CONCEPTS

PhD Project Topic 1.

Experimental: Generate and investigate genotype-phenotype variation for branching and flowering traits exposed using branching network mutant perturbations in designed crossing schemes in combination with the At_DP1001+ lines. This would be a more classical GWAS and genomic prediction project.

PhD Project Topic 2.

Mathematical: Model fitness landscapes for genetic variation for branching and flowering traits that is exposed using branching network mutant perturbations in designed crossing schemes in combination with the At_DP1001+ lines. This would be primarily a mathematical modelling and simulation focused project utilising the data generated from PhD project 1.

PhD Project Topic 3.

Experimental-Mathematical: Predict and test refinements of the current Bertheloot et al. ODE model of the branching network using the experimental and data resources generated from PhD project 1. Use the current model and improvements to test predicted selection trajectories. Owen Powell’s current investigations and predicted selection trajectories based on the Bertheloot et al. ODE model provide a starting hypothesis. A wide range of alternative modelling approaches could be compared as the experimental data become available.

PhD Project Topic 4.

Quantifying uncertainty and model prediction: In this project you will build ensembles (populations of models) calibrated against a variety of data sets. This will allow for a characterisation of the uncertainty in the model parameterisation and the data. These populations of models will then be stressed by external noise processes representing, for example, stochasticity due to climate, and other forms of temporal, variability. This will allow for a characterisation of the long-term robustness and stability of a population of models to external variability, which will be of significant value in a predictive setting.

REFERENCES

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