Maximising crop yield in a changing world: empirical studies and predictive models

Supervisors: Tucker Gilman (FLS), Jenny Rowntree (FLS), Giles Johnson (FLS). **Contact:** tucker.gilman@manchester.ac.uk

Introduction: As the Earth's population continues to grow, we will need to produce more food. To conserve global biodiversity, we will need to produce this food on less land. The challenge is exacerbated by global climate change, which means that crops will be grown under climatic conditions different from those that farmers have experienced in the past. Meeting this goal will require us to understand plant physiology and genetics.

Winter wheat crops of different cultivars grown under drought conditions.

In many crop plants, genetically different cultivars thrive under different conditions. For example, some wheat cultivars are well-adapted to dryer conditions and others are well-adapted to wetter conditions. One way that farmers can minimize the risk of crop failure is by planting cultivar combinations. However, there is growing evidence that different cultivars interact in different ways[1]. For example, cultivar A may thrive when grown with cultivar B, but fare poorly when grown with cultivar C. Moreover, how cultivars interact may depend on the environment. For example, two cultivars that grow well together in wet years may compete intensely and so fare poorly in dry years. These three-way interactions are complex and poorly understood. Studying how genetically different individuals interact in different environments will help ecologists and plant physiologists better understand how ecosystems function, and learning to predict the outcome of these interactions is of societal and economic importance.

Project Summary This project will combine approaches from plant physiology, community genetics, and computational modeling to achieve two goals. First, it will provide a detailed empirical analysis of competition and facilitation between crop cultivars in a variable environment. Second, it will provide a novel predictive tool that will allow agricultural practitioners to select cultivar combinations that maximize yield and minimize risk at their specific cultivation sites. The study will focus on wheat cultivation in the UK, but the tools we develop will be expandable to other crops and other locations.

We anticipate that the project will comprise three parts. Part one will be empirical. The student will grow a number of different wheat cultivars in monocultures and in two-cultivar combinations in growth chambers under different environmental conditions, and will measure the yield and response for each individual plant. The student will use a mixed modeling approach to assess the yield of each cultivar in each environment, and to assess the environment-specific competitive or facilitatory effects within each cultivar pair[2]. In part two, the student will use the data collected in part one to produce a computational model that will identify the combination of cultivars that will maximise the expected yield for any known or anticipated distribution of environmental conditions at a particular site. The model will allow users to maximise yields subject to constraints. For example, users might wish to maximise expected yield while also minimising the risk of very low yields in bad-weather years. In part three, the student will validate the predictions of the computational model by growing a subset of the cultivar combinations from part one in the field under typical agricultural conditions. This will allow the student assess the accuracy of the model predictions, and to further refine the model as necessary.

During this project, the student will receive training in community genetics (Rowntree), plant physiology (Johnson), ecological statistics (Rowntree, Gilman), and computational modeling (Gilman). This PhD would be appropriate for a student with strong quantitative skills and a career interest in basic (*i.e.*, academic) or applied (*i.e.*, industrial) research.

References

1. Rowntree, J. K., D. M. Shuker and R. F. Preziosi. 2011. Forward from the crossroads of ecology and evolution, *Philos. Trans. R. Soc. Lond., B*. 366(1569)1322-1328.
2. Behm, J. E., D. A. Edmonds, J. P. Harmon and A. R. Ives. 2013. Mulitlevel statistical models and the analysis of experimental data. *Ecology* 94(7):1479-1486.