Modelling take-all disease epidemics in winter wheat

As the second largest agricultural crop in the world, wheat and its associated diseases are of great importance. Take-all disease caused by the ascomycete root fungus, *Gaeumannomyces graminis* var. *tritici* (Ggt), infects a variety of cereal crops. The fungus has two phases of infection which deteriorate root function by reducing surface area and damaging the inner cortex as the hyphae grow through the root. This leads to black necrotic lesions forming on the roots and up to 60 % reductions in yield. Levels of take-all infection increase in subsequent years of wheat crop as inoculum accumulates in the soil until the fourth or fifth year of wheat when the build-up of antagonistic microbial organisms in the soil causes take-all decline. There is no complete control mechanism for Ggt, hence understanding the disease-weather interactions could be very useful in helping farmers predict the level of take-all in their crops and therefore decide what crop to grow and what to include as preventative measures.

My project at Rothamsted Research aimed to carry out the initial analysis of this disease-weather relationship by identifying significant correlations between environmental conditions and take-all levels using data from the Broadbalk Long-Term Experiment, the oldest continuous agronomic experiment in the world. Additionally, I sampled the current Broadbalk experiment and assessed the adult root systems for their infection levels.


Aerial photograph of Broadbalk, June 2016 (Image courtesy of Rothamsted Research)

After compiling various disease and meteorological data sets I calculated correlations of the take-all ratings for all second year wheat, third year wheat and for five separate nutrient regimes second year wheat data against seven different monthly meteorological variables. These meteorological variables were; total monthly rainfall, minimum and maximum monthly temperature, average monthly temperature, grass covered soil temperature and bare soil temperature at depths of 10cm and 20cm. I then collated these to produce 2 or 3-year windows summarising correlations for the different disease data sets with each meteorological variable considering the period from when the first year wheat was drilled to the harvest of the second or third year wheat as appropriate.

For each temperature variable with all of the disease data sets, multiple periods of strong positive correlations were found as were fewer, but still notable, periods of negative correlations. These correlations ranged from a maximum positive correlation of 0.579 and a maximum negative correlation of -0.393. When comparing the 2-year time windows of correlations for the five separate nutrient strips the similarity in trends and the strength of correlations demonstrated that the nutrient regime had little effect on the disease-temperature interaction. The total monthly rainfall correlations showed greater variation for all of the disease data sets but especially for the third year wheat data. Again both strong negative and strongly positive correlations were evident in the data.

The take-all ratings I calculated from the 2016 Broadbalk samples that we collected indicate that 2016 was a very high take-all disease year, with a 96.1 % increase in the total average take-all rating for all plots compared to the 1968-2009 average. The reasons for this difference compared to the 30-year mean were explored. The strong positive and negative correlations I identified in my project can now be used for stimulating future research into producing predictive models of the combinations of meteorological variables and time periods which have the greatest effect on take-all prevalence and severity.

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