Investigating gene-environment interactions affecting severity of ash dieback disease

RUSHMORE ESTATE

UNIVERSITY of York

University of Salford MANCHESTER

The Importance of Ash

Ash is a widespread tree within the UK occurring within woodlands, parks and gardens. Ash-dominated woodlands are more prominent than in mainland Europe and Britain **has around 130,000 hectares, making up to 5.5% of the nation's total woodland cover.**

Ash has a special place in the ecosystem function of woodlands, as it lies at the extreme end of the spectrum of UK tree species, with regards to the degradability of its litter. Ash withdraws relatively few nutrients from its leaves, it accumulates relatively little litter and maintains a high nutrient turnover which helps to reduce atmospheric carbon dioxide. It also results in a higher soil pH than other tree species.

These characteristics strongly influence its ecology and drive its inter-relationships with other components of biodiversity, including the associated above- and below-ground species assemblages.

1,058 species have been associated with ash; this is composed of 12 birds, 55 mammals, 78 vascular plants, 58 bryophytes, 68 fungi, 239 invertebrates, and 548 lichens. While ash does not support the large numbers of some species groups (like invertebrates) compared with other tree species such as oak, its loss from the UK will impact on many species. Species of invertebrates, lichens and bryophytes are at most risk from ash dieback when assessed by the number of species affected.

Using a combination of the conservation importance of the species and their level of association with ash, the species that use ash were classified as ***Red, Amber, Yellow and Green with respect to the likely impact of ash dieback*** (red meaning the species is likely to severely decline in population or become extinct, amber and yellow some impact and decline in population, to green, where ash dieback will have little impact). **This gave 69 Red-coded species, 169 Amber-coded species, 383 Yellow-coded species and 330 Greencoded.**
Ash often grows in association with other tree species but there are 8 'National Vegetation Classification' (NVC) sub-communities that are dominated by ash (W8a-e, W8g,d, W8e, W9a & W12a).

Changes in light and soil moisture following the loss of ash from woodlands will be the primary drivers of change in the ground flora community. If the replacement tree species cast a heavier shade than ash (e.g. sycamore, yew, lime) light-loving species within the ground flora community will decline. Larger scale stand collapse will, however, many species reliant on ash as well as the temporary loss of 'forest conditions' which will have far-reaching consequences.

Ash is an important species for timber production both for sawing and for firewood. Its ability to naturally regenerate easily is a major benefit in achieving cost-effective management of broadleaved woodland.

Ash is an important feature of the UK's woodland and countryside and its large-scale loss would have significant impacts on a range of species and habitats and on the economics of broadleaved woodland management.

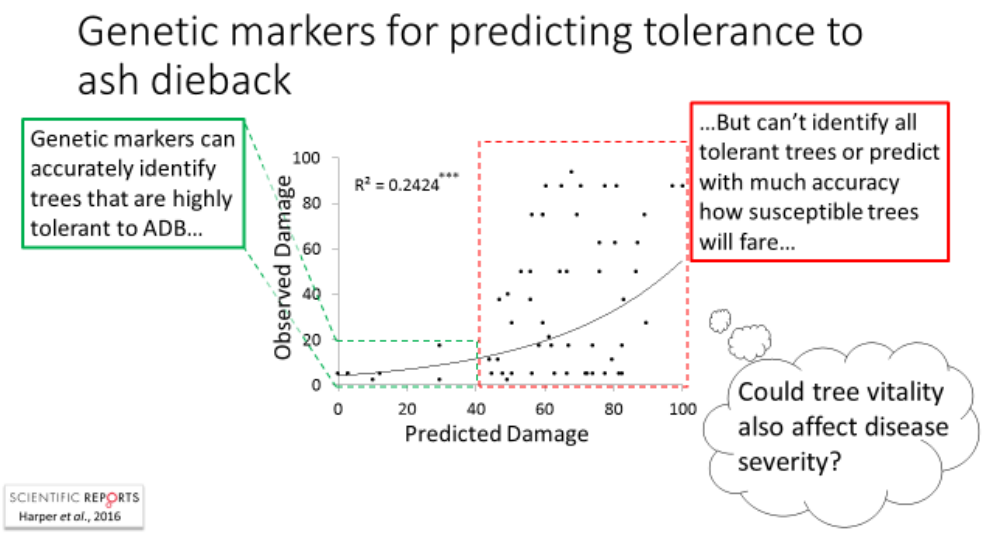
Ash Die-back (ADB)

Invasive pathogens increasingly threaten forest trees globally, endangering their associated biodiversity and reducing the ecosystem benefits (e.g. wood, recreation, soil stability) for humans. Strategies are urgently needed to reduce infection rates and increase the survival of infected forest trees.

This is the case for Europe's ash trees, which have been experiencing high mortality from a fungal pathogen that causes ash dieback disease (ADB); it is now spreading in the UK. We already know that:

- the phenology of autumnal leaf fall is correlated with ADB susceptibility,
- expression levels of several genes are linked to tolerance (part of an induced priming mechanism), and
- genetic markers can identify a subset of tolerant trees.
- there are microbial symbionts in ash leaves that are associated with resistance.

However, like most diseases, susceptibility to ADB is likely to have a strong environmental component, which must be understood before management strategies can be developed.



It is likely that a small proportion of trees have high genetic tolerance to ADB but that for a large, certainly significant proportion of the population, moderate tolerance may be decisively enhanced by good individual tree, and stand, condition, i.e. by appropriate stand management. The corollary is that poor stand condition leading to high levels of stress in its component ash trees will lead to larger-scale loss of ash and more large scale stand collapse.

The Project

The project will evaluate how environmental factors contribute to the spread and severity of ADB, identify situations where ash trees are most likely to survive, and develop effective management strategies. It will investigate:

a) ***Environment***: identify environmental factors associated with the severity of ADB on Fraxinus excelsior trees, including soil type, pH, temperature, humidity, wind speed.

b) ***Management:*** evaluate how stand structure and individual tree character tics (crown size, vigour etc) affect fungal spore production, infection rate, and the condition of un/infected trees.

c) ***Genetics***: measure how gene expression contributes to variation in leaf phenology (spring & autumn), and test how phenology and genotype contribute to tolerance.

d) ***Genetic x Environmental interactions***: quantify how the interactions between environment (from a), management (b) and genotype (c) affect phenology and ADB resistance.

e) ***Microbiome***: identify microbial communities of leaves that reduce *H. fraxineus* infections.

f) **Conservation**: identify environment, management and genotype combinations most resilient to ADB, and develop recommendations for effective management of woodlands (including genetic strategies, e.g. transplants to generate 'resistant phenologies').

ADB severity and gene expression markers (already known to be associated with ADB tolerance) will be assayed for trees in two woodlands, selected for their range of environments, management and tree genotypes. Where appropriate, the project will take advantage of provenance trials (generating locally 'aberrant' phenology) and 'common environment' plantings. Factors contributing to phenology and disease severity will be combined in predictive statistical models for susceptibility, and the accuracy of predictions will be validated.

Project Impact

The project will broaden our understanding of the genetic, phenological and environmental factors involved in determining a tree's susceptibility to ADB, and the biological mechanisms underlying it.

The results of this study will be of interest to researchers studying ADB and other tree pathogens, invasive species more broadly, gene-environment interactions, plant stress responses and plant-pathogen interactions.

The research will be used to identify effective management strategies to improve the resilience of ash woodlands and to reduce the impact of ADB.

University of Salford

The School of Environment and Life Sciences at the University of Salford is a highly integrated unit, which brings together biologists, biomedical scientists, geographers and environmentalists to promote research and teaching in the areas of human and environmental health. The School has significant areas of international strength in research and innovation which is focused in two major research centres. One of which is the Ecosystems and Environment Research Centre (EERC) - an interdisciplinary centre with nearly 40 academics and 40 doctoral students, and as such, the student will be well supoorted within the department. The EERC addresses some of the major environmental challenges of the 21st century relating to ecology, evolutionary biology, biodiversity, infectious diseases and human-wildlife interactions. The concept of Global Ecology within a "One Health" setting, in relation to ecosystem, human and animal health is an important underlying feature to what we do.

University of York

At the last national Research Excellence Framework (REF) assessment, York came top out of all academic institutions for the impact of research outside academia, in the field of Biological Sciences. This illustrates the Department's strong commitment to collaboration with external non-academic partners, and provides the student with an excellent and supportive academic environment in which to develop the impacts of their research.

Rushmore Estate

Rushmore Estate will be one of the key locations for this project. It contains a 400 ha woodland Site of Special Scientific Interest which is largely ash-dominated. The Estate is a leader in the management of native broadleaved woodland including the application of irregular high forest management which has great potential as an effective approach to increasing resilience to ADB. Very active management over the last 30 years has produced a range of stand strictures in ash woodland.

The Estate is currently engaged in a major study into the relationship between stand structure/ management and biodiversity richness.

Key Personnel

Dr Andrea Harper, University of York: leading genetic scientist on ADB and identifier of genetice markers to ADB tolerance.

Dr Rachael Antwis, University of Salford: leading microbial ecologist

Andy Poore, Forestry Consultant, Rushmore Estate; Director, Selectfor Ltd.

Sources

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Costing and Funding Secured to Date

Investigating gene-environment interactions affecting severity of ADB:			
at 11/5/18			
Item	*Contractor*	*Costs (£)*	*Notes*
PhD Studentship	PhD student	94179	
Project Costs	Dr Andrea Harper, University of York	32000	
Academic Support	Dr Andrea Harper, University of York	10000	estimated
Project Costs/ Academic Support	Dr Rachael Antwis, University of Salford	12000	
Project Costs	Travel (various)	4500	
Project Support	Andy Poore, Rushmore Estate	5000	
Total		**157679**	
FUNDING SECURED TO DATE			
University of Salford		81624	Final amount to be confirmed
University of York	Dr Andrea Harper Academic Support	10000	estimated
Rushmore Estate		20000	
Chester Zoo		12000	
DEFRA		15000	To be confirmed
Natural England		5000	To be confirmed
Salisbury Trust		5000	
Hoare Trust		10000	
Total		**158624**	