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Technology transfer to provide genetically improved hardwood tree species for forestry

Key external stakeholders:
Farm foresters, Advisors, Consultants, Nurseries, Forest researchers, DAFM, COFORD

Practical implications for stakeholders:

- Establishment of viable seed producing orchards of sycamore was achieved and the utilisation of seed progeny from these 'Qualified' sources should be encouraged for forest plantations.
- Selected genotypes of wild cherry (*Prunus avium*), developed in Germany have performed better than unimproved Irish saplings in Irish field trials in mixed species plantations.
- The technology for vegetative propagation of ash (*Fraxinus excelsior*) was developed and successfully adopted by a commercial nursery indicating that vegetative propagation of selected ash trees with resistance to dieback disease can be employed on a large scale to produce resistant trees for forestry.

Main results:

1. Genetically improved seeds of sycamore are in production from seed orchards that were established by this project and progeny tests are already established on two sites.
2. Selections of wild cherry performed better than seedling material and are suitable for growing in Irish plantations as a component in mixtures of species.
3. Technology to propagate ash trees vegetatively has been developed and has been successfully transferred and implemented by a commercial nursery with potential to scale up the production of disease resistant genotypes when they are identified and used in the propagation system.

Opportunity / Benefit:

Genetically improved sycamore is becoming available from the seed producing orchards developed in this project; foresters should recommend this material for forests, especially as a temporary ash substitute.
A trial of 31 genotypes of wild cherry (*Prunus avium*) showed at least 8 from Germany performed significantly better than all others in 5 year old trials and grew better than Irish control saplings. The best performing genotypes were: Neptune, Bacchus, Saturn, Neso, Concordia, Pluto, Pomona and Aphrodite. Further data should be recorded to confirm the best performing genotypes over time.
We ascertained the feasibility of transferring the methodology for propagating ash trees vegetatively to a commercial nursery. It showed that a conventional nursery could successfully adopt the propagation methodology and achieve high rooting rates in ash cuttings. This opens opportunities for commercial propagators to scale up the propagation of selections of ash trees which have been screened and confirmed to be highly tolerant to ash dieback disease (Chalara).

Collaborating Institutions:

AFBI, Loughgall N. Ireland; Future Trees Trust UK

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1. Project background:

Sycamore, ash, and wild cherry trees are suitable for farm forestry; they are fast growing species and produce high value hardwood timber. Unfortunately, ash is no longer planted due to the establishment of ash dieback disease in Ireland. Generally, the sources of planting stock of these hardwoods is mainly derived from seeds. However, the seeds used currently are collected mostly from hedgerow trees, or in the case of wild cherry, from the discarded seeds from jam factories. Consequently the growth, stem quality, and other desirable traits have not been selected in the parent trees resulting in very many plantations of low quality and potential. Planting material which can be legally marketed and used in forestry is covered by EU Directive 1999/105/EC in which there are four categories of designation based on genetic quality. These are from lowest grade to highest: 'Source identified', 'Selected', 'Qualified' and 'Tested'. The category 'Selected' consists of stands of trees which display superior traits compared to hedgerow trees (see Figure page 1). Generally, in Ireland, seeds are not collected from such seed stands because stands have not been managed adequately and / or the cost of providing access and seed collection may be too high.
A manageable system of seed collection in the long term is from dedicated seed producing orchards in which the parent trees are highly selected from the entire forest stock in Ireland and the UK. Such was our objective for sycamore i.e. to make available seeds derived from superior genetic mother stocks (Plus trees). Saplings derived from seed orchards are in the improved genetic category of 'Qualified'. Proving the superiority of progeny from seed orchards allows the seeds to be sold in the top genetic category of 'Tested' and therefore progeny tests of sycamore were established.
Apart from the seed orchards as sources of seeds (above) increases in yield and quality of 15-20 % are possible using selected trees that are propagated vegetatively. Wild cherry (*Prunus avium*) grows faster than most broadleaved species in Ireland and has rotations somewhat similar to Sitka spruce. Demand for cherry timber is high and exceeds the supply; productivity and quality can be improved by deploying genetically improved genotypes. Our objective was to test the performance of wild cherry genotypes (developed in the UK and Germany), when planted in intimate mixtures with ash and to compare the growth of improved material to unselected seed derived material as controls.

Our objective for improving the genetic quality of ash for establishing plantations was to develop a system to vegetatively propagate individual genotypes which had been selected among mature individuals as high value and quality Plus trees. This work began before the establishment of ash dieback disease (Chalara). However, the propagation technology developed is directly applicable to propagating individual ash trees which may be selected as disease tolerant. It involves propagating selected trees initially by grafting, followed by micropropagation. We established micropropagated genotypes as pruned 'hedges' that produced cuttings with a high rooting capacity. For the technology transfer component, a set of 10 ash genotypes in the 'hedge' form was transferred to a conventional cutting nursery (Dunne's nursery, Kildare) to ascertain their success rate in adopting the propagation methods developed for ash.

Development work on these species was in close collaboration with the Future Trees Trust in the UK.

2. Questions addressed by the project:

- Is it feasible to establish seed producing orchards of sycamore in Ireland using selected mature Plus trees that are identified in the forest estates of Ireland and the UK?
- Will sycamore seed orchards produce sufficient seeds to establish progeny tests within a few years?
- Can individual genotypes of wild cherry in the 'Tested' category be identified which will outperform seed derived plant material in Ireland?
- Is it feasible to propagate selected genotypes of ash trees vegetatively?
- Is it feasible to transfer the technology for propagating ash trees vegetatively to a conventional nursery for large scale propagation of selected ash trees?

3. The experimental studies:

For sycamore, shoots were collected and grafted from 140 Plus tree genotypes that had been selected throughout the forest estates of Ireland and UK. These Plus trees had superior traits of straight stems, apical dominance and superior growth within mature stands (see Figure, page 1). They were propagated initially by

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grafting and then planted out at Teagasc, Kinsealy in a conservation collection of Plus trees. The trees provided sources of seeds to establish progeny tests and shoots for bulking up sufficient material, by grafting, to establish clonal seed orchards.
Wild cherry selected genotypes (31), and unselected control cherry were trial planted in 2009, in intimate mixtures with ash trees; 4 trees / genotype were spaced at 3m x 4m in an incomplete block design with 6 replicates plots per treatment at AFBI Loughgall. There were 24 named genotypes in the variety SilvaSELECT® which are in the 'Tested' category of genetic quality, developed in Germany. Seven genotypes in the variety Wildstar, developed in the UK were also used. Measurements given are for the growth period 2009-2013.
We aimed to transfer the technology of vegetative propagation of ash, using conventional cuttings, by providing a commercial nursery with the stock plants from which the cuttings could be harvested. Ten genotypes were provided in a pruned 'hedge' form to L&K Dunne Nurseries, Kildare. They harvested twice yearly for three years, standard cuttings were collected and treated in a standard way, and rooting rates per genotype were recorded.

4. Main results:

The collection of Plus trees of sycamore established at Teagasc, Kinsealy has been officially designated as a source of 'Selected' germplasm. From this conservation collection, sufficient material was propagated by grafting (4 ramets per genotype) to establish several clonal seed orchards (CSOs). Two CSOs were established in Ireland, one at None So Hardy nursery Co. Wicklow (2016) and one at AFBI, Loughgall, N. Ireland in 2012 with a tree spacing of 5m X 5m. Using the same complete set of genotypes, a seed orchard was also established by Forest Research in Scotland in 2014. In addition, smaller sets of genotypes were used to establish seed orchards at two sites in England.

Considerable quantities of sycamore seeds had been produced by the conservation collection in 2014 (47kg) and was sold to the nursery trade for production of 'Selected' grade saplings. Seed from individual Plus trees was also harvested and maintained as separate progenies. In 2016, two progeny test were established consisting of 33 families with 30 trees per family on two sites, one in N. Ireland and one in England. Analyses of the growth and development of the families will identify those families with the greatest potential for further genetic improvement. This information will also be useful for the ranking of Plus trees within the established seed orchards with regard to their breeding capacity and will facilitate the selection of Plus tree genotypes for retention or rogueing out.

Total cherry tree height for the growth period 2009 to 2013 was in the range 269 cm (controls) to 379 cm, among the sources of wild cherry tested. The top eight genotypes for total height, in the range of 333 cm to 379 cm was recorded for Neptune, Bacchus, Saturn, Neso, Concordia, Pluto, Pomona and Aphrodite. The first six were also in the top 8 with regard to height increment and also included Hermes and Favonius; the height increment range for the selected genotypes was 286 cm to 309 cm whereas the increment value for unselected control material was 207 cm. The diameter increment at the root collar for the period 2009 to 2012 was in the range 18.6mm (Wildstar-9) to 39.2mm (Bacchus); control value was 24.2mm. The top eight genotypes for stem diameter increment included Neptune, Bacchus, Saturn, Neso, as well as Deo, Eros, and Pluto. These results are encouraging but should be considered as preliminary since the rankings of components will vary as trees develop.

The commercial nursery successfully adopted the vegetative propagation technology developed for ash. Mean rooting rates for the 10 genotypes was 44% in the first year but increased to an overall rate of 89% as the nursery became better acquainted with optimising the management of the 'hedges' that provide the cuttings as well as the rooting procedures and growing conditions. The rooting rate varied slightly between genotypes and the optimal period for cutting collection was mid to late May for the first harvest of cuttings and the second harvest 3-4 weeks later. Rooted cuttings require a growth period of two years in root trainer pots, under protection, before they are large enough for field planting.

5. Opportunity/Benefit:

For sycamore, the collection and propagation of Plus trees in sufficient quantity has facilitated the establishment of several 'Qualified' seed producing orchards in Ireland and the UK. The seeds produces so far have been used to establish progeny tests in Ireland and UK and these require further evaluation as they develop. Seeds from the 'Qualified' seed orchards are of an improved genetic quality and their use by nurseries and foresters should be encouraged in preference to using saplings from unimproved seed sources.

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The growth and development of wild cherry genotypes developed in Germany was superior to home collected seed derived control material. Generally, the genotypes in the UK variety Wildstar performed poorly.
The technology of vegetatively propagating ash by conventional cuttings was shown to be feasible by the successful transfer of this technology to a commercial nursery on a pilot basis. Teagasc has acquired up to 200 genotypes of ash which have been identified as having an improved level of tolerance to ash dieback disease. As dieback disease pressure increases in Ireland, additional tolerant trees will become manifest as healthy trees among those that are dead and dying in plantations. Large scale vegetative propagation of this material and its further screening on infested Irish sites will be a fast means to confirm its tolerance / sensitivity to dieback disease. By scaling up vegetative propagation in conventional nurseries, the large scale deployment of resistant ash trees will be commercially feasible.

6. Dissemination:

Main publications:

Sollars E.S.A., Harper A.L., Kelly L.J., Ramirez-Gonzalez R.H., Swarbreck D., Kaithakottil G., Cooper E.D., Sambles C., Uauy C., Havlickova L., Worswick G., Studholme D.J., Zohren J., Salmon D.L., Clavijo B.J., Zhesi Yi Li He, Fellgett A., McKinney L.V., Nielsen L.R., Douglas G.C., Kjær E.D., Downie J.A., Boshier D., Lee S., Clark J., Grant M., Bancroft I., Caccamo M., Buggs R.J.A. Genome sequence and diversity of European ash trees. Nature 541.7636 (2017): 212-216 url: http://dx.doi.org/10.1038/nature20786

Douglas G.C., McNamara, J., O'Connell, K., Dunne L. and Grant J. (2017): Vegetative propagation of dieback-tolerant Fraxinus excelsior on a commercial scale in: *"Dieback of European Ash (Fraxinus spp.): Consequences and Guidelines for Sustainable Management"* The Report on European Cooperation in Science & Technology (COST) Action FP1 103 FRAXBACK pp. 288-299 Edited by: Vasaitis R. and Enderle R. Publisher: Swedish University of Agricultural Sciences open access at: http://www.slu.se/globalassets/ew/org/inst/mykopat/forskning/stenlid/dieback-of-european-ash.pdf

Douglas G.C., Pliura A., Dufour A., Mertens P., Jacques D., Fernandez-Manjares J.F., Buiteveld J., Parnuta Gh., Tudoroiu M., Curnel Y., Thomasset M., Jensen V., Knudsen M., Foffova E., Chandelier A., Steenackers M. **(**2013) Common Ash (*Fraxinus excelsior*) IN: Forest Tree Breeding in Europe Current state-of-the-art and Perspectives, Managing Forest Ecosystems Vol 25: Springer, ISBN 978-94-007-61 46-9 pp 403-462 .

McCracken, A.R., Douglas, G.C., Ryan, C., Destefanis, M. and Cooke, L.R., 2017. Ash dieback on the island of Ireland. *"Dieback of European Ash (Fraxinus spp.): Consequences and Guidelines for Sustainable Management"* The Report on European Cooperation in Science & Technology (COST) Action FP1 103 FRAXBACK pp. 125-139 Edited by: Vasaitis R. and Enderle R. Publisher: Swedish University of Agricultural Sciences open access at: http://www.slu.se/globalassets/ew/org/inst/mykopat/forskning/stenlid/dieback-of-european-ash.pdf

Popular publications:

Olave R. J and Douglas G.C. (2014) Genetic improvement of sycamore by future trees trust. Forestry and Energy Review Vol 4, 44-46

7. Compiled by:

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