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Location of project:	East Malling Research
Project coordinator:	Mr Nigel Kitney
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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Signature .... Date: 20 September 2015

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Grower Summary

Headline

- East Malling Research (EMR) continues the development of improved rootstocks for apple and pear through breeding and trialling.

Background and expected deliverables

Improved rootstocks are essential for profitable and sustainable production in tree-fruit crops. Factors important to growers include dwarfing (to reduce the cost of pruning and picking), induction of precocious and reliable cropping, freedom from suckers, good anchorage and resistance to pests and diseases. Ease of propagation and good scion-stock compatibility are also important in the nursery.

In 2008, EMR, AHDB Horticulture and the International New Varieties Network (INN) launched a Rootstock Club (EMRC) to breed, develop, distribute and commercialise new rootstock breeding material from EMR, world-wide.

For UK growers, the involvement of AHDB Horticulture in the development of new rootstocks from EMR's programme, will ensure material will be available to UK levy payers. AHDB Horticulture helps to 'steer' breeding objectives to meet the specific requirements of UK growers and ensures that appropriate newly selected rootstocks are trialled further before release to the UK industry.

INN has members in the USA, Chile, South Africa, Australia, New Zealand and throughout Europe. In each country, members can produce virus-free (VF) certified rootstocks and premium quality VF certified finished trees. INN members will arrange, evaluate and select from their own trials to identify those rootstocks best suited to each country's specific growing conditions.

The EMRC aims to develop a range of apple, pear and quince rootstocks to suit different growing conditions. Breeding objectives include:

- new dwarfing and semi-dwarfing stocks for apple and pear
- improved scion-graft compatibility, in particular for pear
- increased precocity and productivity
- increased fire-blight and/or woolly apple aphid resistance

- enhanced tolerance to replant disease

Summary of the project and main conclusions

Crossing programme

- Ten apple and four pear crosses were carried out in May 2014.
- In total, over 2,000 seed from eight of the apple crosses was sown in January 2015. Seed from the other two crosses was retained to increase number in the 2015 crossing, and germination rates from these seed lots were generally good (31-89%) resulting in a good size seedling population.
- A total of 511 seed from two of the pear crosses carried out in 2013 and three of the 2014 crosses was sown in January 2015 and germination was excellent (>80% overall).
- Spare seeds from both apple and pear crosses were stored as back-up.

Seedling populations

- Nearly 1,000 apple seedlings from 13 families raised in the last reporting were planted in August 2014.
- Apple and pear families planted in 2013 were budded in August 2014.

Selection and propagation

- Field records (vigour, crop load and suckering) were taken on existing apple and pear populations.
- Propagation was initiated for apple and pear selections made in 2013 and continues for all genotypes in the current pipeline.
- Seventeen apple selections were made in September 2014. Trees were cut down and earthed up with plastic collars in February 2015.
- Re-propagation of the East Malling apple germplasm collection continued in 2014-15 with grafting completed in March 2015.

Pest and disease screening

- Woolly apple aphid screening was carried out on a total of 44 apple genotypes including advanced and preliminary selections alongside previously characterised controls.

- A GH-based test to test susceptibility to *P. cactorum* was carried out but no disease symptoms were observed.
- Trees of 22 rootstock genotypes were grafted with a common scion to establish a trial plot for Apple Replant Disease tolerance in 2015.

Preliminary trials

- Winter and harvest records were taken from the RF185 trial. This trial was planted with replicates of four selections from apple family M306 (AR86-120 x M20) in 2012. Significant differences in girth measurements were observed. Pruning weights were also recorded.
- In 2014/15 we concluded the evaluation of two trials of rootstocks for pear planted in 2006 (DM177 & DM178). Of the *Pyrus* rootstocks (DM177), four selections (PQ34-1, PQ34-3 and PQ34-6 and PQ35-2) were considered of interest and will be taken forward into a second stage trial. In the quince rootstock trial (DM178), only three selections (PQ5-6, PQ5-8, PQ5-13) were considered sufficiently interesting in comparison with existing quince standards to grant further trialling. All available shoots from these seven selections was taken as hard wood cuttings in February 2015.
- A new preliminary trial of 10 pear rootstocks was planted in 2014.

Financial benefits

- There are major financial implications of developing and selecting rootstocks with improved agronomic performance, including reduced pruning and picking costs and the ability to grow material with reduced pest and disease susceptibility.

Action points for growers

- There are no action points at this stage of the project.

Science Section

Introduction

Improved rootstocks are essential for profitable and sustainable production in tree-fruit crops. Factors important to growers include dwarfing (to reduce the cost of pruning and picking), induction of precocious and reliable cropping, freedom from suckers, good anchorage and resistance to pests and diseases. Ease of propagation and good scion-stock compatibility are also important in the nursery. Whilst there are few international breeding programmes generating tree-fruit rootstocks, East Malling Research (EMR) involvement in rootstock development dates back to its foundation, with the subsequent release of the world-famous series of apple rootstocks; M (Malling) and MM (Malling-Merton in collaboration with the, as was, John Innes Horticultural Institution).

In 2008, EMR, the Horticultural Development Company (HDC, subsequently re-named AHDB Horticulture) and the International New Varieties Network (INN) launched the East Malling Rootstock Club (EMRC) to breed, develop, distribute and commercialise new rootstock breeding material from EMR, world-wide.

For UK growers, AHDB Horticulture also acts as the UK licensee for the EMRC with the intention of making new rootstocks released from EMR's programme widely available to UK levy payers. AHDB Horticulture helps to 'steer' breeding objectives to meet the specific requirements of UK growers and ensures that newly selected rootstocks are trialled further before release to the UK industry.

INN has members in the USA, Chile, South Africa, Australia, New Zealand and throughout Europe. In each country, members can produce virus-free (VF) certified rootstocks and premium quality VF certified finished trees. INN members will arrange, evaluate and select from their own trials to identify those rootstocks best suited to each country's specific growing conditions.

It is not unusual for new rootstock to take 30-35 years to be developed. Selection of parental material, crossing, seedling selection and first stage trialling, which are carried out at EMR, takes around 10 years. Promising material is then propagated and released for AHDB Horticulture-funded trials in the UK and INN-funded trials at appropriate sites around the rest of the world. As trial results accumulate, validating which selections are most promising, these rootstocks are then propagated to build up sufficient material for distribution before it is possible to co-ordinate effective world-wide release.

The EMRC will complete the evaluation of apple, pear and quince rootstock material developed by the former Apple and Pear Breeding Club currently in the pipeline, with the aim to identify a range of apple, pear and quince rootstocks with desirable size control, precocity and productivity, with resistance to diseases and pests where applicable.

Aims and objectives

The EMRC aims to develop a range of apple, pear and quince rootstocks to suit different growing conditions. Breeding objectives include:

- new dwarfing and semi-dwarfing stocks for apple and pear;
- improved scion-graft compatibility, in particular for pear;
- increased precocity and productivity;
- increased fire-blight and/or woolly apple aphid resistance;
- enhanced tolerance to replant disease.

Materials and methods

The breeding programme is an ongoing process, the different steps of which are briefly described below. More details methodology is included in the relevant part of the yearly update as necessary.

<u>Crossing</u>

Parental genotypes that carry one or more phenotypic traits of interest are selected and a crossing programme is designed aiming to combine those desirable characteristic into the resulting seedlings. Controlled crosses are carried out in spring: first, the anthers of the intended male parent are extracted from unopened blossoms to avoid cross contamination and placed in Petri dishes until they dehisce, releasing their pollen. Pollen is stored in a desiccator at 3 °C remaining viable for up to four years. Secondly, petals are removed from the flowers of the intended female (balloon stage) and pollen of the chosen male placed on the receptive stigmas. Fruits are then left to develop and ripen naturally and seeds are carefully extracted after harvest. Fresh seeds are washed and soaked in water for two to three days with daily rinses to remove germination-inhibiting compounds. They are then air-dried and stored at 3 °C until the following January.

Raising seedling populations

Seeds are stratified in the cold-store (between 2 and 4 °C) in trays of moist compost and perlite mix for 16 weeks. After this period, seed trays clearly labelled with progeny numbers are placed in a glasshouse (at ~ 18°C) for germination. Individual seedlings are potted and labelled as they become large enough to handle safely and grown on for around two months. In their first summer, seedlings are planted out in the field and left to establish for a whole growing season.

Field evaluation of rootstock seedlings

In the first winter, 1-year-old bare-rooted plants of commercial standards rootstocks are interspersed in the seedling population as controls. Rootstocks M27, M9, M26 and MM106 are used for apple populations and quince rootstocks EMA and EMC are used in the pear populations. Both seedlings and controls are budded with the same scion the following summer and left to grow. For the three to four years of field establishment of each population, records are taken on each seedling with regards to vigour, production of suckers as well as pest and disease incidence in those suckers. As the common scion comes into fruit, differences attributable to the rootstocks such as fruit size and crop load are also recorded for two season and the most promising seedlings are selected for propagation.

Propagation

Interesting seedlings are selected and marked out with tape in the field during the summer and cut back below the budding union the following autumn. To encourage growth of shoots from the rootstock and their subsequent rooting, stumps are earthed-up with compost in the spring and again during the summer. Leaf samples of each selection are taken at this stage to allow future DNA identification. Pest and disease incidence of the stocks is recorded during the summer and unhealthy selections can be discarded (e.g. severe mildew infection or infestation by woolly apple aphids)

Hardwood cuttings (ideally ~ 30 cm in length) are taken of these selections at the beginning of December and dipped in 0.5% IBA (Indole-3-butryic acid) solution for 5 s prior to insertion into a heated cutting bin to a depth of 6 to 8 cm. The cutting bin consists of 30 cm layer of a 1:1 mixture of peat and fine bark over a 5 cm layer of coarse sand. A soil warming cable maintains bed temperature at 25ºC. Air temperature is cooled via ventilation to outside. Cuttings are left until rooted and then potted into 2 L pots in late January or early February and grown on in unheated glasshouse. Ease of propagation is also a key selection criterion and recalcitrant selections are discarded.

Preliminary trials

After one or two years of growth in pots, selections are grafted with a common scion (currently cv. Gala for apples and cv. Conference for pears) and established in replicated trials that include standard commercial rootstocks for control purposes.

In these trials tree vigour is assessed by the measurement of tree volume (in the form of either the number and length of shoots for trees < 3 years old, or the height and spread of the tree crown for older trees) and by the recording of trunk girth at 15 cm above ground level. Where appropriate, fresh weights at the time of grubbing are also recorded as a measure of relative vigour.

Total yields and yields of class one fruit (> 65 mm and 55-65 mm) are measured for each tree and cumulative yields and yield efficiencies (kg per cm^2 of cross section) are calculated. Records are taken on tree health, graft compatibility and anchorage.

Traditionally, rootstock trials at EMR have not been pruned other than to remove suckers after recording. However, this has not led to the best agronomical evaluation of the new selections. After discussions with the EMRC Executive Management Committee and the AHDB Horticulture Tree Fruit Panel, it was decided to correctively prune ongoing trials and to develop a conservative pruning strategy more in line with commercial orchard practice. Pruning weights were recorded in February 2015 and will continue to be recorded every winter until the end of the trial.

Trials of pear rootstocks (plots DM177 and DM178) were grubbed this year and grubbing weights recorded.

The best selections after this preliminary evaluation are subsequently propagated to enter further trials funded by AHDB Horticulture (TF 172) in the UK and by INN overseas.

Pest and disease resistance screening

Fire-blight (FB)

There was no FB testing in 2014. Shoots of four selections were sent to Agroscope (CH) to be entered into their routine screening. Method and results will be reported in April 2016.

Woolly apple aphid (WAA)

Colonies of *Eriosoma lanigenum* (WAA) collected from the field at EMR are used to challenge rooted cuttings in the glasshouse. Aphids are added to each tree two or three times during July and August. Scoring is carried out at the end of the growing season. Individuals are considered resistant if WAA failed to establish colonies and susceptible if they have succeeded.

Phytophthora cactorum

In collaboration with the EMR pathology group, we are currently developing a pot-based test for determining susceptibility to *P. cactorum*. The experiment carried out in 2014 was mostly aimed to confirm the reliability of the method and the pathogenicity of the available strains of *P. cactorum* using a range of cultivars of known response.

Replant disease

A field area at EMR is currently being set up to evaluate susceptibility of new germplasm to apple replant disease. It will initially compare the performance of a range of established cultivars (and EMR's most advanced selection AR295-6) on un-treated replant soil against that on virgin land and a replant site treated with chloropicrin. Germplasm from the Geneva programme was also sourced for this test in order to confirm the results of North-American trials in the UK. Future testing of advanced selections will depend on the results obtained over the next two to three years on this trial plot and the results of the EMR-led Apple Replant Disease Evolution and Rootstock Interactions (ARDERI) project that started in April 2015 with funding from the BBSRC Horticulture and Potato Initiative II.

Results and discussion

Breeding activities - new seedling populations

<u>Crossing and germination</u>

Seed from the crosses made in April 2014 were extracted in October with variable but generally good results. Details of the cross, including the number of fruit collected and number of seed extracted are shown in Table 1 (apple) and 2 (pear). These tables also show the seed sown in December 2014.

In total, almost 4,000 apple seeds were produced this year, of which 2,338 were sown in December to raise progeny for the 2015 seedling population. Seed was retained from families M595 and M596, and these crosses will be repeated in 2015 and seed accumulated to give larger family sizes. In total, 1,000 seeds of the M589 were planted in 2014, with the surplus being retained as a back-up for future use. This family is particularly large as it aims to pyramid sources of fireblight resistance, which we hope to detect using molecular markers in, at least, part of the population. A larger than usual number of seeds were also sown for the M592 family as previous seed lots from the reverse cross (M561 - M.27 x Geneva 30) showed germination rates of 1% or less in 2011 and 2012 and last year the same cross (M579) produced few seeds, of which less than half germinated. Interestingly, neither was the case for the new family (germination ~ 71%). Poor germination for M561 seed was probably due to an unusual deleterious maternal effect from M27 for this particular parental combination but it would be very difficult to understand the exact mechanism.

For pears, 558 seeds were produced in 2014. Of these seeds 285 were retained in the seed store and the rest (273) were sown together with 238 seeds from the 2014 crosses. More than half the seeds from PRP56 were retained as back-up, as were those from the PRP57 family (cross to be repeated in 2015).

In total, 2,338 apple and 410 pear seeds were sown in December 2014 and stratified at 2°C for 12 weeks. In February 2015, they were transferred to a heated glasshouse with supplementary lighting, as needed for 16h daylight. Germination up to the end of March ranged from 31% for M590 and 89% for M589 in apple (Table 1) and between 65% for PRP54 and 85% for PRP51a in pear and can be considered good overall. Seedlings were potted up in May 2015 weaned and planted in the field in August 2015 and will be budded in August 2016. In order to reduce weeding costs in the first years of the plot and facilitate recording throughout the life of the planting, these populations were planted through Mypex.

Table 1. Summary of results from apple crossing in 2014

Family	Crossed	Cross			# of flowers pollinated	# of fruit set	Seeds		Germinated 03/2015
		Female	x	Male			Produced	Sown	
M587	2014	CG 202	x	AR295-6	103	49	248	150	91
M588	2014	AR295-6	x	CG 202	45	16	113	113	76
M589	2014	Evereste	x	CG 30	508	506	2295	1000	890
M590	2014	M13 F	x	M116	282	56	134	134	42
M591	2014	M.M.106	x	CG 30	209	68	131	131	107
M592	2014	CG 30	x	M27	160	129	543	543	385
M593	2014	Bud 9	x	Evereste	306	130	117	117	91
M594	2014	Novole	x	M.116	451	135	298	150	54
M595	2014	A469-4	x	MH.12.3	16	3	2	0	0
M596	2014	M13 F	x	Bud 9	286	27	69	0	0
				Total	451	135	3950	2338	1736

Table 2. Summary of results from pear crossing in 2014

Family	Crossed	Cross			# of flowers pollinated	# of fruit set	# seeds		Germinated 03/2015
		Female	x	Male			produced	sown	
PRP51a	2013	OHxF87	x	P525-3	-	-	-	121	104
PRP53	2013	OHxF333	x	BP1	-	-	-	117	83
PRP54	2014	OHxF51	x	Pyronia (x2)	219	40	52	52	34
PRP55	2014	Old Home	x	BP3	249	55	21	21	16
PRP56	2014	P298-18	x	Kumloi	272	88	470	200	173
PRP57	2014	OHxF69	x	BP2	217	49	15	0	0
				Total	957	232	558	511	410

Table 3. Apple rootstock germination and seedlings planted in 2014 (Plot SC204)

Family	Cross	Year of crossing	Seeds		Germination	Planted
			Sown	Trays		
M573	Bud 9 x Evereste	2013	**12**	1	50%	**6**
M574	Evereste x M9	2013	**345**	7	86%	**298**
M575	M9A x Evereste	2013	**14**	1	45%	**6**
M576	A469-4 x MH.10.1	2013	**40**	1	65%	**26**
M577	Evereste x Geneva 30	2013	**12**	1	45%	**5**
M578	Geneva 11 x AR295-6	2013	**67**	2	96%	**64**
M579	Geneva 30 x M27	2013	**29**	1	49%	**14**
M580	Geneva 30 x AR295-6	2013	**171**	4	85%	**144**
M581	M27 x Geneva 11	2013	**47**	1	88%	**41**
M582	MM106 x Geneva 30	2013	**39**	1	91%	**35**
M583	Torstein x M27	2013	**242**	5	86%	**208**
M584	Torstein x M9	2013	**133**	3	95%	**125**
M585	M9 EMLA x Sally	2013	**31**	1	35%	**10**

Establishment and budding

Over 980 apple seedlings from 13 progenies (Table 3) were planted in August 2014 in double rows (plot SC204). Establishment and survival was good and these will be budded in August 2015.

The apple (plot SP246) and pear (plot SP247) populations planted in 2013 (Tables 4 and 5) were budded in August 2014 with cvs. SA544-28 and Concorde respectively. The only exception was 100 seedlings from the PRP52 population for which we will evaluate rooting behaviour before carrying out other evaluations. This part of the family will be treated as mini-stool beds for the next four-five years.

Table 4. Apple rootstock seedling population planted in August 2013 and budded in August 2014 (Plot SP246)

Family	Cross	Year of crossing	Germination	Planted
M566	Budagovsky 9 x Evereste	2012	2013	17
M567	M27 x Geneva 11	2012	2013	11
M568	Torstein x M27	2012	2013	4
M569	Torstein x M9	2012	2013	11
M570	Geneva 202 o.p.	2012	2013	88
M571	Geneva 11 o.p.	2012	2013	80

Table 5. Pear rootstock seedling population planted in August 2013 and budded in August 2014 (Plot SP247)

Family	Cross	Year(s) of crossing	Planted	Seedlings
PRP49a	PB11-30 OHxF333	2010	2013	69
PRP50a	OHxF87 x BP1	2010	2013	132
PRP51	OHFx87 x P525-3	2011&12	2013	4
PRP52	B13 x P525-3	2011&12	2013	351*

* 100 seedlings were not budded and will be earthed up in 2015

Seedling populations in the pipeline and selection

Apple

In total, 14 apple families were assessed for vigour, crop load and suckering in September 2014. This included the progenies planted in 2010 [M553 (AR86-1-20 x Geneva 202), M554 (MM106 x Geneva 30), M555 (Geneva 30 x OP) and M556 (Ottawa 3 x OP)] which were first budded in 2011 with ~ 35% of seedlings being reworked the following year; as well as the seedlings from the 2011 populations in plot SC198 [M557 (M116 x M.9), M558 (Geneva 30 x M116), M559 (Bud 9 x M9), M560 (AR86-1-20 x Geneva 11), M561 (M27 x Geneva 30), M562 (MM106 x Geneva 202), M563 (MM106 x Bud 9)] for which budding took first time round in 2012. Approximately 30% of seedlings from families M557 to M563 failed to take initially and were re-worked in 2013 and they will be recorded for the first time in 2015. Additionally, families M550 (AR86-1-20 x M9 EMLA), M551 (M116 x M9a), M552 (White Angel x M9 EMLA) planted in 2007 (plot SC194) and worked with cv. SA544-28 a year later were also recorded for the final time and nine, two and six selections were made from each respectively (Table 6.1.).

The three tentative selections made in 2013 from family M580 (unknown pedigree) in plot SC190 were also recorded (Table 6.2.) and only one individual (#4) of them was retained and chosen for propagation and the only one of them exhibiting and reasonably crop load of good size. This selection was also re-named as M510-4 (as this family number was never allocated) to fit in with expected chronological ordering of family names and to avoid confusions with the existing numbering system for which family numbers have already reached ‘580'. All of these selections were cut down in winter 2014-15 and earthed-up using plastic pots as collars to encourage suckering and rooting for propagation.

Table 6.1. Apple selections made in summer 2014

Plot	Selection	Vigour			Crop load*			Suckering		
		2012	2013	2014	2012	2013	2014	2012	2013	2014
SC194	M550-12	w	-	vw	-	-	l	+	-	0
SC194	M550-22	mw	-	w	-	-	h	+	-	++
SC194	M550-25	w	-	vw	-	-	l	0	-	0
SC194	M550-30	w	-	vw	-	-	h	0	-	0
SC194	M550-32	m	-	mw	-	-	vh	+	-	+
SC194	M550-40	m	-	m	-	-	h	+	-	+
SC194	M550-41	mw	-	w	-	-	m	0	-	0
SC194	M550-55	w	-	vw	-	-	m	0	-	0
SC194	M550-67	mw	-	m	-	-	mh	0	-	0
SC194	M551-8	m	m	mw	-	0	h	+	++	+
SC194	M551-50	mw	mw	m	-	0	m	+	++	+
SC194	M552-43	m	mw	w	-	0	mh	+	0	+
SC194	M552-55	mw	mw	mw	-	mh	0	+	++	+
SC194	M552-89	m	m	m	-	0	ml	+	0	+
SC194	M552-92	mw	m	m	-	0	m	+	0	+
SC194	M552-108	m	mw	mw	-	0	m	+	++	+
SC194	M552-111	w	w	w	-	0	l	+	++	+

Table 6.2. Selections made in 2013 and re-evaluated in 2014

Plot	Selection	Vigour				Crop load*					Suckering			
		2010	2011	2012	2014	2010	2011	2012	2013	2014	2010	2011	2012	2014
SC190	M510*-4	mw	w	mw	mw	0	0	0	ml	mh	-	-	-	-
SC190	M510-16	w	mw	w	w	0	0	0	ml	0	+	-	-	-
SC190	M510-32	w	w	mw	mw	0	0	0	m	vl	-	-	+	-

* family previously named as M580

<u>Pear</u>

The following families were also assessed for suckering and bud-take in September 2014: PRP45 (PB11-30 x OHxF87), PRP46 (B14 x op), PRP47 (BP1 x *P. betulifolia*), PRP48 (OHxF333 x Junsko Zlato), PRP49 (PB11-30 x OHxF333), PRP50 (OHxF87 x BP1) but no selection was due.

Propagation

Propagation via hard-wood cuttings of apple and pear selections in the pipeline for pest and disease screening and/or trial was carried out later than usual in the reporting period. Whilst cuttings would have normally been taken in December 2014, this activity was postponed until the beginning of February 2015 due to the wet and mild weather during the autumn. The number of cuttings taken from apple and pear genotypes has been summarised in Tables 7.1 and 7.2 respectively. Attempts to continue propagation of all surviving genotypes will be made in 2015-16.

Additionally, the re-propagation of EM apple germplasm collection continued in the winter of 2014-15 with grafting of genotypes missed or failed the previous year. Trees propagated in 2013-14 will be planted in the spring 2015 and genotyped to verify trueness to type in the summer/autumn. Any trees found to be not true to type will be grubbed and re-propagated from the existing genebank in 2015-16 and subsequently verified.

Table 7.1. Cuttings taken from apple selections in February 2015

Plot	Selection	Selection year	Number of cuttings[1]		
			Collected from field		Placed into the bin (Feb 2015)
			Hardwood	Rooted	
SC181	M430-217	2010	-	-	-
SC181	M430-249	2010	-	2	2
SC181	M432-203	2010	2	3	4
SC181	M432-217	2010	-	-	-
SC181	M432-243	2010	-	-	-
SC181	M432-247	2010	-	4	0
SC181	M432-250	2010	-	-	-
SC183	M480-3	2011	7	2	10
SC183	M481-5	2011	-	-	-
SC183	M481-10	2011	4	3	3
SC183	M482-11	2011	-	8	8
SC183	M482-13	2011	-	8	9
SC183	M482-42	2011	1	-	0
SC183	M482-44	2011	5	8	10
SC183	M482-49	2011	5	5	6
SC183	M482-54	2011	-	4	7
SC183	M482-65	2011	-	-	-
SC183	M482-84	2011	-	-	-
SC183	M482-87	2011	3	-	1
SC183	M482-110	2011	-	-	-
SC183	M482-133	2011	-	-	-
SC183	M482-153	2011	-	-	-
SC183	M482-158	2011	11	8	8
SC183	M482-175	2011	4	4	5
SC184	M508-1	2012	2	12	11
SC184	M508-22	2012	1	2	0
SC184	M508-41	2012	-	4	6
SC184	M508-49	2012	-	1	1
SC190	M509-22	2012	12	2	16
SC190	M545-50	2012	-	-	-
SC190	M545-57	2012	-	4	4
SC190	M545-58	2012	-	-	-
SC190	M545-145	2012	-	14	13
SC190	M546-9	2012	-	-	-
SC190	M546-22	2012	-	9	10
SC190	M546-110	2012	20	3	7
SC190	M546-125	2012	6	-	1
SC190	M547-1	2012	24	3	9
SC190	M547-8	2012	12	8	12
SC190	M547-41	2012	14	3	7
SC190	M547-72	2012	5	-	2
SC190	M548-2	2012	1	-	1
SC190	M549-59	2012	-	6	5
SC190	M549-83	2012	-	6	5
SC190	M549-94	2012	3	-	2
SC190	M549-122	2012	-	-	-
SC190	M549-146	2012	3	4	6

[1]The numbers of cuttings that go into the bin may be different from the sum of those collected as a consequence of cuttings collected from the field being too small or soft (decrease) or where additional cuttings can be taken from a single, long hardwood cutting (increase).

Table 7.2. Cuttings taken from apple selections in February 2015

Plot	Selection	Selection year	Number of cuttings[1]		
			Collected from field		Placed into the bin (Feb 15)
			Hardwood	Feb 2015	
SC185	**PQ41-9**	2012	2	6	6
SC185	**PQ41-26**	2012	-	-	-
SC185	**PQ41-52**	2012	-	-	-
SC185	**PQ41-57**	2012	-	-	-
SC185	**PQ41-60**	2012	2	1	2
SC185	**PQ41-61**	2012	-	-	-
SC185	**PQ41-63**	2012	-	-	-
SC193	**PQ42-11**	2013	1	3	4
SC193	**PQ42-23**	2013	-	6	6
SC193	**PQ42-33**	2013	7	-	0
SC193	**PQ42-47**	2013	8	-	3
SC193	**PQ42-50**	2013	4	-	0
SC193	**PQ42-138**	2013	1	2	3
SC193	**PQ43-34**	2013	9	-	0
SC193	**PQ43-42**	2013	3	-	0
SC193	**PQ43-50**	2013	2	-	2
SC193	**PQ43-57**	2013	-	-	-
SC193	**PQ44-10**	2013	4	-	1
SC193	**PQ44-11**	2013	13	1	0
SC193	**PQ44-26**	2013	24	-	8

[1]The numbers of cuttings that go into the bin may be different from the sum of those collected as a consequence of cuttings collected from the field being too small or soft (decrease) or where additional cuttings can be taken from a single, long hardwood cutting (increase).

Screening advanced selections for pest and disease

Advanced and preliminary selections from the apple breeding programme are currently undergoing a range of tests for pest and disease resistance.

<u>Fire-blight (FB)</u>

No tests for resistance to fire-blight were carried out in 2014 as our arrangement of testing through the Swiss nursery LUBERA came to an end during this year. However, a new arrangement has been reached with Agroscope (CH) to test our selections from 2015. Graftwood from four advanced selections and two controls were sent to Wädenswil in January for inoculation by Markus Kellerhals's team (Table 8). These experiments will confirm previous results for three selections which have showed intermediate/inconclusive results (highlighted in Table 9) and provide information on another (AR440-1) not previously tested.

Table 8. Apple genotypes to be tested for fire blight (FB) resistance in 2015 by Agroscope

Genotype	Parentage	Previous data on response to FB	No. of shoots provided
AR295-6	*M. robusta* 5 x Ottawa 3	Intermediate/Variable	12
AR835-11	M.I.793 x M9	Possibly intermediate	12
AR839-9	M7 x M27	Possibly intermediate	12
AR440-1	M25 x M27	Not tested	12
CG-935	Ottawa 3 x *M. robusta* 5	Resistant	12
M.9	Unknown	Susceptible	12

Table 9. Summary of fire blight (FB) resistance screening for nine EMR rootstock genotypes following repeated inoculation with *Erwinia amylovora* isolates 'Ea782', 'Ea797' and 'Ea914' in 2012 and 'Ea797', 'Ea839' and 'Ea951' in 2013

Genotype	2012			2013		
	# of reps	% of necrosis		# of reps	% of necrosis	
		Range	Average		Range	Average
AR10-2-5				9	54.8-100	87.0
AR10-3-9	7	47.1- 100	77.9	6	60.3-85.7	66.2
AR295-6				7	2.6-25.0	10.0
AR680-2				6	65.0-100	82.0
AR809-3	8	16.7 - 100	73.6			
AR835-11	5	4.3 - 95.2	52.5	7	21.0-82.4*	41.7
AR837-19				10	18.2-73.9	44.4
AR839-9	8	1.7 - 100	40.8	1	n.a.	28.6
AR852-3	5	47.1 - 100	80.1			
B24	4	21.1- 100	72.6			
R104	4	53.3 - 100	76.6			
R59	8	58.1 - 100	83.6			
R80	6	19.2 - 100	68.3			
M9 T337	7	19.2 -100	68.9	6	16.0-100	47.5
Supporter 4				5	52.9-83.3	69.1

* all except one < 50%

Woolly apple aphid (WAA)

Following problems in 2012 and 2013 to collect sufficient aphids to initiate screening early in the season, aphid colonies were overwintered in susceptible trees first in the EMR nursery. Trees were given four months in the cold store (~ 2°C) to ensure sufficient chill but avoiding frost and then transferred to the glasshouse in April. As we hoped, the aphid colonies thrived early in spring 2014. Additionally, the mild winter followed by an early spring allowed WAA populations in un-sprayed plots and gardens across the South East of England to build up quickly. As a result, we had no shortage of healthy WAA adults to initiate our screen and the first 18 genotypes (mostly advanced selections) alongside M27 and M116 (Table 9) that started with a first round of inoculation on 14 May. Additional genotypes were added throughout the summer as space in the compartment become available. Each tree showing no colonies was inoculated up to four times, recorded two weeks after inoculation and then moved out of the compartment if a conclusive score was reached. Thanks to the abundance of aphids, we were able to add 13 preliminary selections and several control genotypes to the screen in mid-July and August. (Table 9.2).

In total, two selections and one control genotype (M25) returned conflicting or unexpected results and they will be re-tested in the future after trueness-to-type is confirmed with molecular markers. In the late screening, seven selections were confirmed as susceptible and 10 need to be retested.

Table 9.1. Advanced and trial selections tested for WAA resistance in GH screen at EMR in 2014 starting in May 2014

Selection number	Parentage		Woolly apple aphid		2014	
	♀	♂	Response[1]	EMR[2]	Trees tested	Score
AR10-2-5	MM106	M27	?	2014	3	Resistant
AR10-3-9	MM106	M27	Susceptible?	2014	5	Susceptible
M27	**M9**	**M13**	**Susceptible**		**3**	**Susceptible**
M116	**M27**	**MM106**	**Resistant**		**3**	**Resistant**
AR295-6	Robusta 5	Ottawa 3	Susceptible	✓	2	Susceptible
B24	AR10-2-5	AR86-1-22	Resistant?	2014	2	Resistant
R59	AR134-31	AR86-1-22	Susceptible?	2014	0	2015
R80	AR134-31	AR86-1-22	?	2014	0	2015
R104	AR134-31	AR86-1-22	?	2014	1	died/2015
AR628-2	Ottawa 3	MM106	?	2014	6	Susceptible
AR680-2	M26	M7	Susceptible?	2014	3	Susceptible
AR682-6	M26	M.I.793	?	2014	6	Resistant
AR440-1	**M25**	**M27**	**Susceptible?**	**2014**	**0**	**TBC[3]**
AR486-1	Ottawa 3	M7	Susceptible?	2014	3	Susceptible
AR801-11	M26	M1	Susceptible	2014	2	Susceptible
AR809-3	R80	M26	?	2014	4	Resistant?
AR835-11	M.I.793	M9a	Susceptible?	2014	5	Susceptible
AR837-19	M3	M1	?	2015	3	Susceptible
AR839-9	**M7**	**M27**	**Susceptible?**	**2015**	**3**	**TBC[3]**
AR852-3	AR362-16	op	Susceptible?	2015	0	2015
M306-6	AR86-1-20	M20	?	2014	4	TBC[3]
M306-20	AR86-1-20	M20	?	2014	4	TBC[3]
M306-79	AR86-1-20	M20	?	2014	3	Susceptible
M306-189	AR86-1-20	M20	?	2014	2	Susceptible

[1] If known or with'?' if expected due to parentage or unconfirmed
[2] Confirmed EMR (2012 or 2013) or indicating year test is planned for
[3] Contrasting results; it will be necessary to verify trueness-to-type of individual trees and/or re-test

Table 9.2. Genotypes tested for WAA resistance in GH screen at EMR, from July to September 2014

Selection number	Parentage ♀	Parentage ♂	2014 Trees tested	2014 Score
M432-217	M27	MM106	4	Re-test[1]
M432-250	M27	MM106	4	Susceptible
M482-11	M9	M116 or CG202	4	Re-test[1]
M482-13	M9	M116 or CG202	4	Re-test[1]
M482-153	M9	M116 or CG202	4	Susceptible
M482-158	M9	M116 or CG202	4	Susceptible
M482-175	M9	M116 or CG202	4	Susceptible
M482-49	M9	M116 or CG202	4	Re-test[1]
M482-54	M9	M116 or CG202	4	Re-test[1]
M482-84	M9	M116 or CG202	4	Susceptible
M482-87	M9	M116 or CG202	4	Susceptible
M546-110	M9	JM7	4	Re-test[1]
M546-125	M9	JM7	4	Re-test[1]
M546-22	M9	JM7	4	Re-test[1]
M546-9	M9	JM7	4	Re-test[1]
M547-1	M9	*M. floribunda* 821	4	Susceptible
M549-83	M13	JM7	4	Re-test[1]
M.25	N. Spy	M2	3	No symptoms[2]?
M.26	M16	M9	6	Susceptible
AR295-6	Controls		3	Susceptible
M.116	Controls		3	Resistant
M.M.106	Controls		3	Resistant
CG11	Controls		3	Resistant
CG16	Controls		3	Resistant
CG41	Controls		3	Resistant
CG202	Controls		3	Resistant
CG935	Controls		3	Susceptible

[1] Showed not symptoms until the last inoculation and then only very few aphids presents or colonies developed only in one of the trees- TBC
[2] Known susceptible genotype, might not be true-to-type

Phytophthora cactorum

In collaboration with our pathology group, we have started to re-establish a routine pot screen for collar rot. This year we set up a replicated experiment with 13 genotypes (M116, CG-16, AR839-9, M27, CG-202, CG-935, AR295-6, CG-41, CG-11, M26, M25, Pajam 2), of, mainly, known response to assess the test itself. Unfortunately, the pathogenic strained isolated by EMR staff in 2013, failed to thrive when plated up therefore a UK-native *P. cactorum* isolate was obtained from FERA in spring 2014. Three successive inoculations (using respectively, zoospore solution, mycelial discs in the surface of the compost and mycelial plugs placed under the bark), in a glasshouse (GH) at controlled temperature, failed to produce any symptoms in known susceptible genotypes (Fig. 1). We have concluded that the isolate is not pathogenic in apple and the test will have to be repeated in 2015. A request to UK growers for sources of inoculum resulted in three isolates being collected and analysed by pathologists at EMR. Only two of those isolates grew well in culture and will be used to inoculate in 2015.

Figure 1. *P. cactorum* experiment in GH_C19

Apple Replant Disease (ARD)

Progress to establish a new trial for ARD tolerance continued in 2014 with the land being prepared including the fumigation of one area with chloropicrin. In all, between nine and 12 rootstock liners of 22 rootstock genotypes (Table 10) were budded with a columnar scion in Feb 2015 for this trial, which was planted in the summer of 2015. Phenotyping for symptoms and soil sampling will be carried out in collaboration with the ARDERI project.

Table 10. Genotypes grafted with columnar scion in February 2015 for ARD trial plot

Source	Rootstock	Parentage	Reported ARD response
Dalicom	**CG-11**	M.26 x *M. robusta* 5	Susceptible
Dalicom	**CG-16**	Ottawa 3 x *M. floribunda*	Partial tolerance
Dalicom	**CG-202**	M.7 x *M. robusta* 5	Tolerance
Dalicom	**CG-41**	M27 x *M. robusta* 5	Tolerance
Dalicom	**CG-935**	Ottawa 3 x *M. robusta* 5	Tolerance
IFO	**AR10-2-5**	MM106 x M27	TBD
IFO	**AR10-3-9**	MM106 x M27	TBD
IFO	**AR440-1**	M25 x M27	TBD
IFO	**AR486-1**	Ottawa 3 x M7	TBD
IFO	**AR628-2**	Ottawa 3 x MM106	TBD
IFO	**AR680-2**	M26 x M7	TBD
IFO	**AR835-11**	M.I.793 x M9a	TBD
IFO	**AR837-19**	M3 x M1	TBD
IFO	**AR839-9**	M7 x M27	TBD
IFO	**AR86-1-20**	MM106 x M27	TBD
FP Matthews	**M116**	MM106 x M27	Tolerance TBC
FP Matthews	**M25**	Northern Spy x M2	Tolerance TBC
FP Matthews	**M26**	M16 x M9	Susceptible
FP Matthews	**M27**	M13 x M9	TBD
FP Matthews	**M9**	Unknown	Susceptible
FP Matthews	**MM106**	Northern Spy x M1	Partial tolerance
IFO	**AR295-6**	*M. robusta* 5J x Ottawa 3	TBD

Preliminary trials

Apple (plot RF185)

This trial, planted in March 2012, compares four selections from the M306 family (AR86-1-20 x M20) grafted with cv. Gala to three control rootstocks: M9, M116 and MM106. Fruit was harvested in September 2014 and winter records completed in January 2015. Growth and harvest data from this trial are shown in Tables 11.1 and 11.2. In addition, following decisions agreed with the AHDB Horticulture Tree Fruit Panel and the Management Committee of the EMRC, pruning weights were taken from this trial for the first time (Table 11.3). Annual pruning will be carried out every winter after growth measurement are taken and provide additional information on vigour and labour intensity of management for each rootstocks.

In terms of rootstock effect there were significant differences in girth, tree volume and yield efficiency, but not any significant effects in terms of yield and numbers of fruit produced. The controls continued to behave as expected.

Table 11.1. The effects of apple rootstocks on the growth of cv. Gala trees in 2014 (plot RF185).Trees planted March 2012

Rootstock	2014 data		
	Girth (cm)	Tree volume (m³)	Yield efficiency (kg/cm²)
M306-6	8.3*a*	2.7*ab*	0.7*c*
M306-20	7.8*a*	3.6*a*	0.9*bc*
M306-79	5.9*bc*	1.5*bcd*	2.0*a*
M306-189	4.0*d*	0.7*d*	1.9*ab*
M9	5.6*c*	1.2*cd*	1.9*ab*
MM106	7.3*ab*	2.4*abc*	1.4*abc*
M116	7.4*a*	2.7*ab*	0.8*c*
SED (18 d.f.)	*0.7*	*0.6*	*0.5*
Significance	***	**	*
LSD p=0.05	*1.4*	*1.3*	*1.0*

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect and letters show the least significant difference

Table 11.2. The effects of apple rootstocks on the yield of cv. Gala trees in 2014 (plot RF185). Trees planted March 2012

Rootstock	Mean yield per tree (kg)			Mean number of fruit per tree		
	≥65mm	<65mm	Total	≥65mm	<65mm	Combined
M306-6	0.7	2.2	2.9	5.5	23.8	29.2
M306-20	0.6	2.8	3.4	4.8	35.5	40.2
M306-79	0.8	3.3	4.1	6.3	37.2	43.5
M306-189	0.4	1.6	2.0	3.0	18.5	21.5
M9	0.4	3.1	3.5	3.3	34.5	37.8
MM106	1.1	3.9	5.0	8.5	56.0	64.5
M116	0.6	2.3	2.9	5.0	27.8	32.8
SED (18 d.f.)	*0.4*	*1.0*	*1.2*	*3.1*	*12.8*	*13.4*
Significance	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
LSD p=0.05	*0.8*	*2.1*	*2.5*	*6.4*	*26.9*	*28.1*

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect

Table 11.3. Pruning weights from cv. Gala apple trees on M306 rootstocks in 2015 (plot RF185)

Rootstock	Pruning weight (g)
M306-6	289
M306-20	313
M306-79	114
M306-189	37
M9	232
MM106	162
M116	230
SED (18 d.f.)	*68*
Significance	**
LSD p=0.05	*142*

Summarising for each selection in turn:

- **M306-6**: Similar in many respects to M116 with very similar tree volume, yield efficiency and fruit yield. Although mean girth measurements appeared larger and fruit size was greater than in M116 these differences were not significant. This selection, along with M116, gave the lowest yield efficiency, significantly lower than for two of the other selections (M306-79 and M306-189) and M9 control.
- **M306-20:** This selection had the greatest tree volume of all the selections trialled, although this was not significantly different from MM106 or M116. Total yield was intermediate between MM106 and M116 but with a trend for smaller fruit, although again these differences were not significant.
- **M306-79:** Similar in many respects to M9, with girth and tree volume being slightly higher than with M9, although not significantly so, but with identical yield efficiency. Total yield was also very similar with a trend towards larger fruit than M9 (not significant) in contrast to the results from 2013 where fruit size was judged to be inferior.
- **M306-189:** This selection had a significantly narrower girth than all the other selections, and a small tree volume, almost half of that of M9, although this was not significant. Total yield was lower than for the other stocks, again not significantly so, but interestingly the yield efficiency was identical to M9.

Completed pear and quince trial (DM177 and DM178)

The evaluation of two trials of rootstocks for pear planted in 2006 (plots DM177 and DM178) came to an end in the 2014-15 season. Plots DM177 and DM178 were harvested in September 2014 and winter records and grubbing weights of the tree cut above the graft union were recorded in January 2015. Both trials include quince rootstock controls EMA and EMC, the latter from two different sources which continue to perform differently.

Pyrus rootstocks (DM177)

Yield and growth records are shown in Tables 12.1 and 12.2 and crop alternation is shown in Figure 2. A short summary of the most interesting rootstocks from the trial is shown below:

- **PQ34-1:** Slightly lower tree volume compared to EMA (non-significant or ns). Similar yield efficiency and fruit size, but lower cumulative yield.
- **PQ34-3:** Similar in most respects to EMA but with significantly larger tree volume.

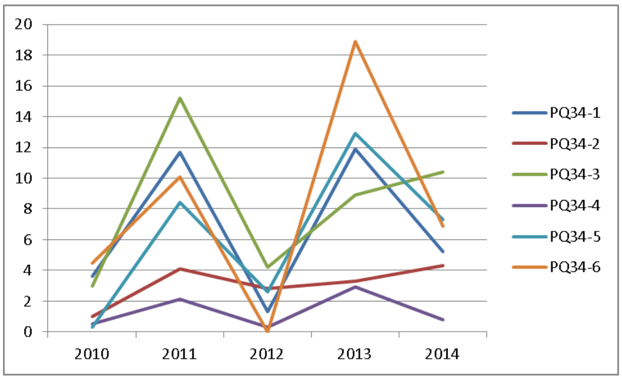
- **<u>PQ34-6:</u>** Slightly smaller tree than EMA (ns) but similar cumulative yield and yield efficiency. Fruit size appeared to be smaller than on trees on PQ34-3 or EMA but this was not significant.
- **<u>PQ35-2:</u>** The best selection of the more dwarfing family (PQ35) that is slightly smaller than EMC but also has a significantly lower cumulative yield.

At the January 2015 meeting of the EMRC, it was decided that the following selections showed most promise and would be taken forward for further trials: PQ34-1, PQ34-3, PQ34-6 and PQ35-2. Additionally, PQ35-3 (most dwarfing in the trial) will be retained as a breeding line.

Table 12.1. The yield pattern of *Pyrus* and Quince (QA and QC) rootstocks produced in 2010-14. (plot DM177). Trees planted March 2006. Selections already in propagation are underlined and those being taken forward are shaded

Rootstock	Total yield (kg/tree)					
	2010	2011	2012	2013	2014	Cumulative (2007-2014)
PQ34-1	3.6	11.7	1.3	11.9	5.2	36.5
PQ34-2	1.0	4.1	2.8	3.3	4.3	16.6
<u>PQ34-3</u>	3.0	15.2	4.2	8.9	10.4	48.7
PQ34-4	0.5	2.1	0.3	2.9	0.8	6.9
PQ34-5	0.3	8.4	2.6	12.9	7.3	33.9
<u>PQ34-6</u>	4.5	10.1	0.0	18.9	6.9	47.5
PQ35-1	0.4	1.0	4.1	3.8	0.9	12.5
<u>PQ35-2</u>	1.2	2.7	0.1	4.2	0.4	19.4
PQ35-3	0.0	0.3	4.3	0.1	0.7	6.3
EMA	1.9	11.8	2.6	17.3	8.0	46.8
EMC ex Blackmoor	0.4	4.5	1.9	12.8	5.1	29.1
EMC ex Keepers	2.5	9.7	1.3	14.4	8.7	41.9
SED (38 d.f.)	1.3	2.4	4.2	5.0	3.9	8.8
Significance	**	***	ns	***	**	***
LSD p=0.05	2.6	4.9	8.6	10.0	7.8	17.8

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect



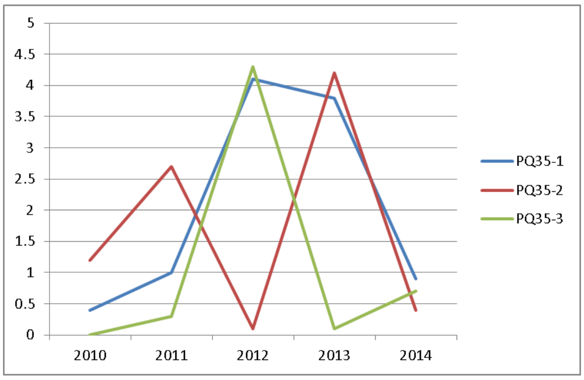


Figure 2. The yield (kg/tree) pattern of PQ34 and PQ35 rootstocks in 2010-14 (plot DM177). Trees planted in March 2006

Quince rootstocks (plot DM178)

Yield and growth records are shown in Tables 13.1 and 13.2 and Figure 3. A number of selections appear comparable to the control, although overall yields are lower than in 2013. Conclusions are particularly difficult to reach in this trial due to the very low level of replication for many of the stocks. Comparisons therefore rely on means and trends where statistical significance is absent. Notes on the most interesting rootstocks follow:

- **PQ5-6**: This rootstock gave the highest cumulative yield in trial (65.3kg/tree) and was not dissimilar to EMA in terms of tree girth and volume. Over 50% of fruit was graded within the 55-65mm category, compared to 40% with EMA.
- **PQ5-8:** Gave the highest mean total yield in 2014 (14 kg/tree) that was significantly greater than produced by the controls. 81% of fruit was graded >55mm, with the majority of fruit (55%) being graded between 55-65 mm. Slightly more dwarfing than EMA.
- **PQ5-12:** Was the most dwarfing of all the rootstocks tested with a lower tree volume than EMC (ns) and EMA ($P < 0.05$). It had previously been identified as promising but gave a disappointing total yield; lower than all but two other rootstocks. Cumulative yield was lower than the EMC (ns) and EMA ($P < 0.05$) controls although yield efficiency was similar to EMA and the mean of the two EMC stocks.
- **PQ5-13:** Had the highest yield efficiency in the trial, significantly greater than for the EMA and EMC controls. It had similar vigour to EMC but almost double the 2014 total yield (ns) and with excellent fruit size; > 90% graded > 55mm compared to 73% with EMC and 83% with EMA.
- **PQ5-16:** Slightly larger tree than EMA (ns) with similar yield efficiency but with a higher total and cumulative yield (ns).
- **PQ5-18:** Slightly more vigorous than EMA but with similar yield efficiency and slightly higher total cumulative yield (ns). Fruit size smaller than EMA (ns).
- **PQ5-22**: Similar in all respects to EMA.

It was agreed at the January 2015 EMRC meeting that the following selections showed most promise and would be taken forward for further trials: PQ5-6, PQ5-8 and PQ5-13. Other selections that had appeared interesting in previous years were not considered sufficiently different from existing rootstocks to warrant further evaluation.

All available shoots from these seven selections was taken as hard wood cuttings in February 2015 and propagation for secondary stage trials is ongoing.

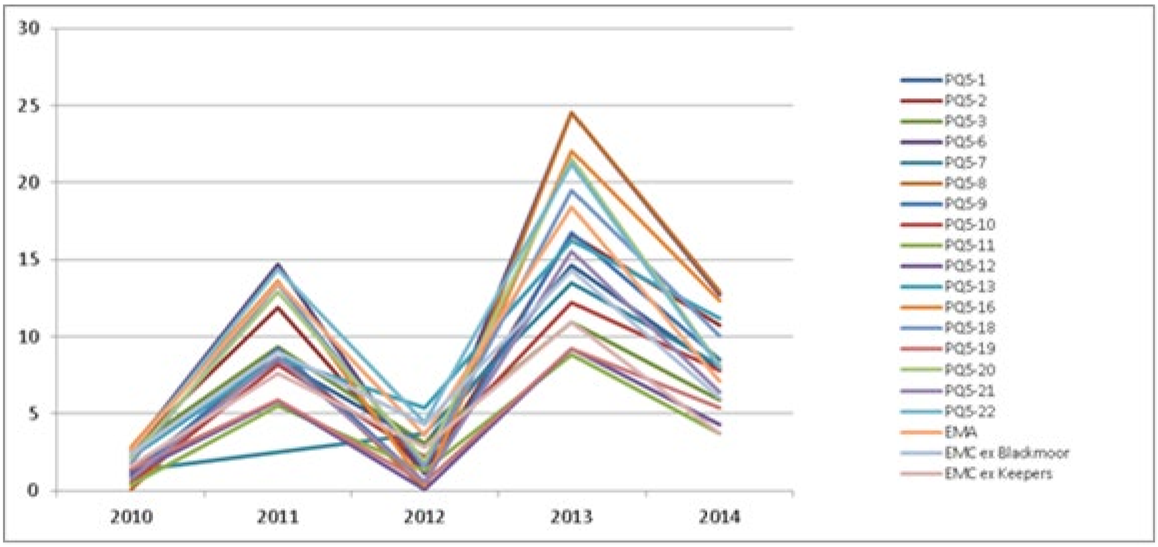


Figure 3. The yield (kg/tree) pattern of PQ5 series (Quince) rootstocks in 2010-14 (plot DM178). Trees planted March 2006

Table 13.1. The yield pattern of PQ5 (Quince) rootstocks in 2010-14 (plot DM178). Trees planted March 2006. Selections already in propagation are underlined and those being taken forward are shaded

	Total yield (kg/tree)					
Rootstock	**2010**	**2011**	**2012**	**2013**	**2014**	**Cumulative (2007-2014)**
PQ5-1	1.3	8.5	3.0	14.6	7.7	40.3
PQ5-2	2.6	11.9	1.1	16.6	10.7	50.8
PQ5-3	2.7	9.3	3.1	10.9	5.9	37.8
PQ5-6	2.6	14.7	1.1	24.5	12.7	65.3
PQ5-7	1.3	2.5	3.7	13.5	8.1	33.9
PQ5-8	0.1	9.2	0.1	24.5	14.0	60.5
PQ5-9	0.9	9.2	0.5	16.7	8.5	38.2
PQ5-10	0.5	8.2	2.2	12.2	7.9	33.2
PQ5-11	0.4	5.5	1.3	8.8	3.7	21.1
PQ5-12	1.1	5.8	0.1	9.2	4.3	24.2
PQ5-13	2.2	8.6	5.4	16.2	11.2	50.6
PQ5-16	2.8	13.6	0.3	22.0	12.3	59.1
PQ5-18	1.8	13.4	1.6	19.5	10.0	56.9
PQ5-19	1.4	5.9	0.5	9.2	5.5	26.0
PQ5-20	2.1	12.9	1.9	21.5	8.1	52.0
PQ5-21	0.8	8.6	0.6	15.5	6.4	37.9
PQ5-22	2.5	14.4	4.4	21.2	8.0	59.2
EMA	2.6	13.5	3.6	18.4	7.3	53.2
EMC ex Blackmoor	2.4	9.0	4.3	14.3	6.0	42.3
EMC ex Keepers	1.6	7.6	2.8	10.9	3.7	36.1
SED (48 d.f.)	1.40	3.56	2.8	5.8	3.1	11.4
Significance	ns	**	ns	*	**	***
LSD p=0.05	2.82	7.15	5.6	11.7	6.2	22.8

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect

Table 12.2. The effects of Pyrus and Quince (QA and QC) rootstocks on the growth and cropping of Conference pear trees in 2014 (plot DM177). Selections already in propagation are underlined and those being taken forward are shaded

Rootstock	Growth parameters			Yield (kg/tree)								Cumulative yield (kg/tree)		Yield efficiency (kg/cm²)
	Girth (cm)	Tree Volume, (m³)	Tree weight (kg)	Total,	>65mm	55-65mm	*60-65mm*	*55-60mm*	*50-55mm*	*<50mm*	Waste	Total	>65mm	
PQ34-1	21.9	11.2	11.2	5.2	2.1	2.0	*1.3*	*0.7*	*0.6*	*0.4*	0.1	36.5	7.4	2.5
PQ34-2	15.4	7.5	5.4	4.3	0.2	2.6	*1.2*	*1.4*	*0.7*	*0.6*	0.2	16.6	1.6	2.0
<u>PQ34-3</u>	24.5	22.7	9.6	10.4	3.9	4.4	*2.7*	*1.7*	*1.2*	*0.7*	0.2	48.7	9.0	2.5
PQ34-4	11.7	2.6	2.7	0.8	0.0	0.2	*0.0*	*0.2*	*0.2*	*0.5*	0.0	6.9	0.3	0.9
PQ34-5	16.9	6.9	6.5	7.3	1.5	1.9	*0.8*	*1.1*	*1.7*	*2.3*	0.0	33.9	4.2	2.7
<u>PQ34-6</u>	18.0	12.6	7.2	6.9	2.2	2.4	*0.9*	*1.4*	*0.8*	*1.3*	0.2	47.5	4.5	2.8
PQ35-1	12.2	3.8	2.8	0.9	0.1	0.4	*0.1*	*0.3*	*0.3*	*0.1*	0.0	12.5	1.2	1.8
<u>PQ35-2</u>	14.2	2.8	3.4	0.4	0.0	0.1	*0.1*	*0.0*	*0.0*	*0.2*	0.0	19.4	1.6	1.6
PQ35-3	8.2	1.1	1.2	0.7	0.4	0.3	*0.0*	*0.3*	*0.0*	*0.0*	0.0	6.3	3.0	4.7
EMA	20.7	13.6	10.0	8.0	4.1	2.9	*2.0*	*1.0*	*0.4*	*0.2*	0.3	46.8	9.0	2.5
EMC ex Blackmoor	13.7	5.0	3.7	5.1	0.4	2.6	*1.3*	*1.3*	*1.0*	*0.9*	0.2	29.1	2.2	3.3
EMC ex Keepers	17.8	8.2	6.0	8.7	1.1	5.1	*2.3*	*2.8*	*1.2*	*1.2*	0.2	41.9	3.2	2.7
SED (38 d.f.)	2.2	3.3	2.9	3.9	1.6	2.9	*1.5*	*1.6*	*0.8*	*0.7*	0.3	8.8	2.9	1.0
Significance	***	***	***	**	***	ns	*ns*	*ns*	*ns*	*ns*	ns	***	***	ns
LSD p=0.05	4.4	6.8	5.8	7.8	3.3	5.9	*3.0*	*3.2*	*1.5*	*1.3*	0.7	17.8	5.8	1.9

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect

Table 13.2 The effects of PQ5 series (Quince including QA and QC) rootstocks on the growth and cropping of Conference pear trees in 2014 (plot DM178). Trees planted March 2006. Selections taken forward are highlighted and those previously in propagation are underlined

Rootstock	Growth parameters			Yield (kg/tree)								Cumulative (kg/tree)		Yield efficiency (kg/cm^2)
	Girth (cm)	Tree Volume, (m^3)	Tree weight (kg)	Total	>65mm	55-65mm	*60-65mm*	*55-60mm*	*50-55mm*	*<50mm*	Waste	Total	>65mm	
PQ5-1	17.9	8.4	6.8	7.7	1.1	4.1	*2.4*	*1.7*	*1.4*	*1.1*	0.1	40.5	5.2	2.9
PQ5-2	19.6	9.0	7.5	10.7	2.6	4.9	*2.4*	*2.5*	*1.8*	*0.9*	0.6	50.8	6.3	2.8
PQ5-3	15.7	8.6	5.0	5.9	2.1	3.0	*2.0*	*1.0*	*0.3*	*0.4*	0.1	37.8	5.3	3.3
PQ5-6	21.7	11.9	10.3	12.7	3.4	6.7	*4.3*	*2.3*	*1.3*	*0.7*	0.7	65.3	6.0	2.9
PQ5-7	15.7	5.4	5.0	8.1	2.0	4.7	*2.7*	*2.0*	*0.1*	*1.1*	0.3	33.9	5.6	2.9
PQ5-8	19.2	12.2	7.8	14.0	1.2	10.0	*7.6*	*2.4*	*1.4*	*1.2*	0.2	60.5	7.1	3.5
PQ5-9	17.8	7.9	6.6	8.5	3.8	3.2	*2.0*	*1.3*	*0.7*	*0.4*	0.4	38.2	5.4	2.5
PQ5-10	17.7	9.9	6.7	7.9	2.0	3.6	*2.3*	*1.3*	*1.3*	*0.6*	0.4	33.2	5.0	2.2
PQ5-11	16.5	8.2	5.9	3.7	2.5	1.1	*0.9*	*0.2*	*0.1*	*0.1*	0.1	21.1	3.7	2.1
PQ5-12	14.4	4.3	3.7	4.3	2.1	1.5	*1.1*	*0.4*	*0.2*	*0.1*	0.4	24.2	4.3	2.7
PQ5-13	16.8	8.6	6.9	11.2	7.4	2.8	*1.6*	*1.3*	*0.4*	*0.3*	0.3	50.6	12.6	4.7
PQ5-16	22.2	18.7	11.2	12.3	5.1	5.3	*3.7*	*1.6*	*0.7*	*0.8*	0.3	59.1	9.1	2.7
PQ5-18	20.9	15.1	8.9	10.0	1.3	6.4	*4.0*	*2.4*	*1.2*	*0.6*	0.5	56.9	7.4	3.0
PQ5-19	14.2	5.1	4.1	5.5	2.0	2.9	*2.1*	*0.9*	*0.2*	*0.1*	0.3	26.0	3.3	2.9
PQ5-20	19.0	8.3	6.9	8.1	3.4	2.9	*2.0*	*1.0*	*1.0*	*0.2*	0.7	52.0	7.9	3.2
PQ5-21	16.3	5.8	4.6	6.4	0.9	3.8	*2.4*	*1.3*	*0.6*	*0.9*	0.3	37.9	1.8	2.9
PQ5-22	22.3	13.0	10.4	8.0	1.8	4.2	*2.8*	*1.4*	*0.3*	*0.5*	0.4	59.2	11.1	2.4
EMA	20.9	13.6	9.7	7.3	3.0	3.1	*2.0*	*1.0*	*0.6*	*0.2*	0.4	53.2	10.5	2.7
EMC ex Blackmoor	15.4	8.8	5.4	6.0	0.4	2.2	*1.0*	*1.2*	*1.2*	*2.0*	0.2	42.3	4.4	3.4
EMC ex Keepers	17.0	6.9	5.0	3.7	1.4	1.3	*0.6*	*0.7*	*0.4*	*0.6*	0.1	36.1	5.4	2.3
SED (48 d.f.)	2.5	4.0	2.0	3.1	1.6	2.2	*1.4*	*1.1*	*0.8*	*0.8*	0.4	11.4	2.6	0.6
Significance	***	***	***	**	***	*	**	*ns*	*ns*	*ns*	ns	***	***	**
LSD p=0.05	5.1	8.0	4.1	6.2	3.2	4.4	*2.8*	*2.2*	*1.7*	*1.7*	0.8	22.8	5.3	1.2

*, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effects

Newly planted pear trial (plot RF187)

Additionally, a new preliminary trial of 10 pear selections was planted in August 2014 with Quince EMA as the only control (EMC grafts failed in 2013).

Root samples were taken of all plants prior to planting. DNA was extracted and fingerprinting using SSRs carried out to establish trueness-to-type. Only one of the spare trees was found to be not-true-to-type and was discarded. Additionally, one allele in one of the 12 markers used ('137' in marker CH02b12) was missing from the profiles of all but one of the trial and spare trees of genotype PQ37-3. This allele is present in the mother plant and in one of the trial trees. These results were confirmed by fresh DNA extraction and testing. No other pear trees propagated at the same time or in our rootstock database matched the profile for these samples, making an error during propagation improbable. The discrepancy is most likely due to a point mutation in the area of the SSR, which is a non-coding region, and therefore unlikely to have any effect on the phenotype and performance of the rootstocks. As no other trees where available for replacement, the suspect trees have been retained and will be carefully monitored during the life of the trial.

In the late summer of 2014, one of the trees in the field died and it was replaced with a spare true-to-type equivalent kept in the nursery in spring 2015. Guards worked with cv. Williams to act as a pollinator variety were also planted at the same time.

To improve the uniformity of management of the trail, trees were all cut back to a single whip at around 1-1.2 m for the ground in March 2015 and first growth records will be taken in 2015-16.

Row	Tree	Block	Pos.	Rootstock
1	1			Williams
1	2	1	1	PQ39-4
1	3	1	2	PQ38-2
1	4	1	3	PQ39-1
1	5	1	4	PQ37-3*
1	6	1	5	Quince A
1	7	1	6	PQ37-8
1	8	1	7	PQ37-7
1	9	1	8	PQ39-5
1	10	1	9	PQ37-5†
1	11	1	10	PQ39-3
1	12	1	11	PQ37-2
1	13			Williams

Row	Tree	Block	Pos.	Rootstock
2	1			Williams
2	2	2	1	PQ38-2
2	3	2	2	PQ39-3
2	4	2	3	PQ37-2
2	5	2	4	PQ39-4
2	6	2	5	PQ37-3
2	7	2	6	PQ37-7
2	8	2	7	PQ37-5†
2	9	2	8	Quince A
2	10	2	9	PQ39-1
2	11	2	10	PQ37-8
2	12	2	11	PQ39-5
2	13			Williams

Row	Tree	Block	Pos.	Rootstock
3	1			Williams
3	2	3	1	PQ37-3
3	3	3	2	PQ39-4
3	4	3	3	PQ37-7
3	5	3	4	PQ37-5†
3	6	3	5	PQ38-2
3	7	3	6	PQ39-3
3	8	3	7	PQ37-8
3	9	3	8	PQ37-2
3	10	3	9	PQ39-1
3	11	3	10	Quince A
3	12	3	11	PQ39-5
3	13			Williams

Row	Tree	Block	Pos.	Rootstock
4	1			Williams
4	2	4	1	PQ37-3
4	3	4	2	Quince A
4	4	4	3	PQ37-5
4	5	4	4	PQ37-2
4	6	4	5	PQ39-3
4	7	4	6	PQ37-7
4	8	4	7	PQ39-4
4	9	4	8	PQ39-5
4	10	4	9	PQ38-2
4	11	4	10	PQ39-1
4	12	4	11	PQ37-8
4	13			Williams

* Replaced with GH spare in Spring 2015
† One allele in 1 of 12 markers is missing from the DNA of the trees.

Figure 4. Plot plan for new pear preliminary trial (RF 187) planted in 2014

Planned crossing programme for 2015

Apple

The main aim of the apple programme is to introduce pest and disease resistance into the Malling breeding lines, with particular emphasis on resistance to fire blight (FB) and woolly apple aphid (WAA) in order to produce resistant, dwarfing and/or semi-dwarfing rootstocks. We also aim to introduce heat tolerance and improved water use efficiency (WUE) in combination with suitable nursery characteristics and appropriate vigour. In spring 2015 we aimed to repeat a number of the crosses that were not very successful in the last couple of years, as well as try to incorporate new germplasm into the breeding programme. Parents included:

- **M13:** dwarfing rootstock, parent of M27 poorly characterised in resistance to many diseases but likely tolerant to replant disease;
- **M116** (MM106 x M27): semi-vigorous (~ to MM106), very resistant to crown and collar rots, WAA resistant, fairly good WUE, low suckering, hard to propagate;
- **MM106**: semi-vigorous, WAA resistant, fairly good WUE, low suckering, relatively easy to propagate;
- **A469-4** [Howgate Wonder x (*Malus platycarpa* x M26)]: very resistant to mildew, not very vigorous;
- **AR295-6** (*M. robusta* 5 x Ottawa 3): promising dwarfing selection, WAA susceptible;
- **Hibernal:** tetraploid, very resistant to mildew, easy rooting;
- **Budagovsky 9** (M8 x Krasny Shtandard): selected in Poland, dwarfing (~ M9), precocious, winder hardy, fairly fireblight resistant in the field, collar-rot resistant, moderate resistance to mildew and scab in the nursery;
- **Geneva 11** (M26 x *M. robusta* 5): dwarfing (~ M9), very precocious, good yield efficiency, adequate rooting, low suckering, no burr-knots, fairly resistant to fireblight, moderately WAA resistant;
- **Geneva 30** (M26 x *M. robusta* 5): dwarfing (~ M9), very precocious, good yield efficiency, adequate rooting, low suckering, no burr-knots, fairly resistant to fireblight, moderately WAA resistant;
- **Geneva 202** (M27 x *M. robusta* 5): semi-dwarfing (~ M26, ~ 45-55% of seedling stock), high yield efficiency, WAA resistant; crown rot and fireblight resistant;
- **Hashabi (MH) 10.1, 12.3, 14.5 & 16.7**: very good heat-tolerance, vigorous, productive, some susceptibility to nematodes, highly susceptible to mildew;
- **Evereste:** Ornamental *Malus*, source of fire blight resistance;

- **Torstein:** Scion cultivar, highly resistant to *P. cactorum;*
- **Novole:** North American accession of moderate to low vigour, reportedly resistant to *P. cactorum* as well as vole damage.

Pear

The main aim of the pear programme is to produce improved, fully compatible *Pyrus* rootstocks with a range of vigour with good pest and disease resistance that are precocious and easy to propagate. It is anticipated that at least two controlled crosses will be carried out using parents from the list below in suitable combinations:

- **OHxF51:** (Old Home x Barlett*), dwarfing rootstock, moderately susceptible to fire-blight;
- **OHxF69:** (Old Home x Barlett*), dwarfing rootstock;
- **OHxF333:** (Old Home x Barlett*) semi-dwarfing rootstock of some commercial interest, precocious, promotes early spurring, slightly more dwarf than OHxF 97, reportedly fireblight resistant/tolerant;
- **BP2:** South African rootstock; not dwarfing but roots reasonably well;
- **BP3:** South African rootstock, similar vigour and better crop than BP2, not easy to propagate;
- **Pyronia:** Pear x quince hybrids; compact habit;
- **Pyrodwarf:** semi-vigorous, fire blight resistant, <u>reportedly</u> precocious (yet to flower at EMR);
- **Old Home:** Fireblight resistant, rather invigorating, excellent compatibility bridge for quince, resistant to pear decline, easily propagated by hardwood cuttings;
- **Farmingdale:** Fire-blight resistant (if tree flowers at the NFC, Brogdale; efforts to introduce in EMR collection will also continue).

*previously attributed to Farmingdale. It is now clear, thanks to DNA evidence, that the reported parentage is not possible and cv. Barlett is the most likely parent. As a result, FB resistance from Farmingdale is not adequately represented in the rootstock genepool and so steps have been started to re-introduce it.

Conclusions

Promising progress has been made to date and further trialling and crossing will be done.

Knowledge and Technology Transfer

Progress was summarised in both the AHDB Tree Fruit Review and at the AHDB / EMRA Tree Fruit Day in 2015.