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Project leader:	Felicidad Fernández, NIAB EMR
Report:	Annual report, 2015-16
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Key staff:	Felicidad Fernández Adam Whitehouse
Location of project:	East Malling Kent
Industry Representative:	Nigel Kitney, H L Hutchinsons Ltd
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[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

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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GROWER SUMMARY

Headline

- NIAB EMR continues to develop improved rootstocks for apple and pear through breeding and trialling our own selections as well as material from other breeding programmes.

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 (now NIAB EMR), the HDC (now 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 East Malling, world-wide.

For UK growers, the AHDB involvement in the development of new rootstocks from NIAB EMR's programme will ensure material will be available to UK levy payers. The AHDB 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

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 were observed in girth and tree volume, but not any significant effects in terms of yield, cumulative yield, yield efficiency, numbers of fruit produced or pruning weights at this stage
- Preliminary records were taken for the trial of ten new pear rootstock selections planted in 2014. There were significant differences even at this early stage in terms of girth and numbers of suckers, but not any significant effects in terms of height. One of the rootstocks (PQ37-3) appears to have some compatibility problems with Conference with half the trees dying in Year 1

Second stage trials

- In the conventional trial planted in 2010 (EE207), where five new selections are being evaluated with Braeburn and Gala for a vigour range between M.27 and M.26, full harvest and winter records were taken and significant differences were found for all parameters measured. R59 continues to produce the smallest trees (~M.27) and has the highest yield efficiency but overall yield and size are not very encouraging. AR852-3 and AR839-9 are larger trees but produced much better yields of fruit (> 65 mm).
- In the low-input orchard also planted in 2010 (VF224), the four selections being trialled are evaluated with Red Falstaff. Full harvest and winter measurements were taken and R80 continues to be the most productive rootstock but it is also significantly more vigorous that M.116 and MM106. So far, AR10-3-9 is the closest in size to the control but seems to require significantly more pruning for comparable yields.
- The new trial evaluating Canadian rootstocks has been fully genotyped. Due to the large (10%) error rate in propagation or labelling, the trial design is unbalanced and the preliminary vigour data collected in 2015 was subjected to regression analysis but it is far too early to comment on any of these rootstocks.

Crossing programme

- Eight apple and three pear crosses were carried out in April-May 2015.
- In total, over 3,500 seeds from eight of the apple crosses were sown in December 2015 and germination rates from these seed lots were generally very good resulting in a population of 1,822 seedlings.
- No pear populations were raised in 2015.

- Spare seeds from both apple and pear crosses were stored as back-up.

Seedling populations

- A total of 1,342 apple seedlings from 8 families and 406 pear seedlings from five families raised in the last reporting were planted in August 2015 through mypex.
- Apple and pear families planted in 2013 were budded in August 2014.

Selection

- Field records (vigour, crop load and suckering) were made on existing apple and pear populations.
- Seventeen preliminary apple selections were made in September 2015 but they will be propagated, if retained, in 2017-18 with any other selections from the same families made in summer 2016.

Pest and disease screening

- Fireblight screening of four advanced selections in Agroscope (CH) confirmed the previously observed low susceptibility of AR295-6 and indicate that AR835-11 and AR839-9, although susceptible, are significantly less so than M.9. AR440-1 is also less susceptible than M.9 but should be considered fully susceptible.
- The glasshouse assay to test susceptibility to *P. cactorum* is still being developed and no results can be reported for 2015.
- A reduced number of genotypes were planted in a plot with both treated and untreated soils to evaluate the impact of Apple Replant Disease in different rootstocks.
- Screening by inoculation with woolly apple aphid was not particularly conclusive as the aphids failed to establish well in some well-known susceptible cultivars.

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

- At this stage in the breeding programme, no action points have been identified for growers.

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, NIAB 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 M.M. (Malling-Merton in collaboration with the, as was, John Innes Horticultural Institution).

In 2008, EMR (now NIAB EMR), the AHDB Tree Fruit Panel 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. The programme has been renewed several times since and current funding incorporating breeding, preliminary trialling and UK second stage trials runs until 2020.

For UK growers, the AHDB 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 also helps to 'steer' breeding objectives to meet the specific requirements of the 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 in the EU (represented by EVI). 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. Selection of parental material, crossing, seedling selection and first stage trialling, which are carried out at NIAB EMR, takes around 10 years. Promising material is then propagated and released for AHDB-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 APBC 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 effort of which different steps are briefly described below. More detailed methodology is included in the relevant part of the yearly update as necessary.

Preliminary trials

After one or two years of growth in pots, selections are grafted with a common scion (currently 'Gala' for apples and '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 NIAB 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 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 so every winter until the end of the trial.

The best selections after this preliminary evaluation are subsequently propagated to enter the second stage trials funded by AHDB Horticulture under this same project (TF224) in the UK and by INN overseas.

Second stage trials (previously under AHDB Horticulture project TF172a&b):

They are performed as above but usually with greater level of replication as more material is available per genotype and, in the case of apple, can involve more than one scion cultivar. During the reporting year, three second stage apple trials were evaluated (EE207 involving NIAB EMR genotypes in conventional growing conditions, VF224 involving NIAB EMR genotypes under low-input conditions and the recently planted SP250 that will assess

Canadian rootstocks in a newly planted conventional apple trial.

Breeding activities:

Crossing

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 the dehisce releasing their pollen. Pollen is stored in a desiccator at 3 °C. This pollen can remain viable for up to 4 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 for 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 ‘M.27’, ‘M.9’, ‘M.26’ and ‘M.M.106’ are used for apple populations and quince rootstock ‘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% (Indole-3-butryic acid) IBA solution for five seconds 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 25 ºC. 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.

Pest and disease resistance screening

Fire-blight (FB)

Shoots of four selections were sent to Agroscope (CH) to be entered on their routine screening. Genotypes were grafted on rootstock M9vf T337 in rose pots (35.5 cm pot height, 7 cm in diameter, 12 replicate trees per genotype). 'Gala Galaxy' was included as a susceptible control, 'Enterprise' as a resistant control. Grafted genotypes were grown up during five weeks in a greenhouse (temperature: 16-24 °C, humidity: 65%).

After five weeks, the plants were transferred to the security greenhouse GX. Plants with minimum shoot length of 14 cm were inoculated on 13 April 2015 as described by Momol et al. (1998). Inoculum Erwinia amylovora (Swiss strains FAW 610 Rif, specified concentration = 109 cfu/ml-1) was introduced to the shoot tip by inserting a syringe of 0.7mm diameter (22 gauge) through the stem just above the youngest unfolded leaf. The length of the optical fire blight-free shoot part as well as the length of necrotic lesion (cm) was measured 7, 14 and 21 days after inoculation. To estimate susceptibility, percent lesion length (lesion length divided by shoot length) was calculated for each time point. Measurements were taken in the following dates (20.04.2015; 27.04.2015 and 04.05.2015).

Woolly apple aphid (WAA)

Colonies of *Eriosoma lanigenum* (WAA) collected from the field in Kent are used to challenge rooted cuttings in the glasshouse. Aphids are added to each tree 2-3 times during July and August. Scoring is carried out at the end of the growing season. Individuals will be 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 but it did not proved too effective. In 2015, a similar test was carried out with new isolates.

Replant disease:

An area of fields 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 yeas on this trial plot and the results of the NIAB 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

Preliminary Trials

Apple trial (RF185)

Fruit was harvested form this trial in September 2015 and winter records completed in January 2016. Data from this trial is shown in Tables 1 and 2 and Figure 1.

In terms of rootstock effect there were significant differences in girth and tree volume, but not any significant effects in terms of yield, cumulative yield, yield efficiency, numbers of fruit produced or pruning weights. A summary of the performance of each rootstock is shown below:

M306-6	As in 2014, this selection was **similar** in many respects to **M116** with a very similar tree volume, yield efficiency and total yield in 2015. Although mean girth measurements, fruit size and yield were greater than in M116 these differences were not found to be significant. In addition, this stock has the highest cumulative yield of all the stocks in the trial, including the standards. However it was noted that one tree was suffering from canker in January 2016.
M306-20	The mean **tree volume** for this stock was **significantly greater** than all other stocks in the trial and had the greatest weight of wood removed during pruning (ns). The total yield of M306-20 in 2015 was the second highest, only being surpassed by M306-6. This was reflected in the high cumulative yield, similar to MM106, although these differences were found not to be significant. However, as in previous years, **yield efficiency** was one of the **lowest** but comparable to M116.
M306-79	M306-79 was **similar to M9** in terms of vigour, with identical mean girth and similar tree volume (slightly larger although not significant). In 2015 it gave a higher (ns) yield and yield efficiency than M9 but with similar fruit size (>55mm: 94% for M306-79 v 95% for M9). In 2014 the trend was towards larger fruit than M9 (ns) in contrast to the results from 2013 where fruit size was judged to be inferior. This stock gave the second highest cumulative yield (after M306-6), although this was not significant.
M306-189	This stock had a significantly narrower girth and **smaller tree volume** than the other stocks in the trial, with tree volume being approximately one-third of the volume of M9. Total and cumulative yields were lower than for all the other stocks (not significant) but yield efficiency was the highest (ns). **Fruit size** was generally **smaller**, having the highest percentage (20%) of fruit graded at <55mm.

Table 1. The effects of apple rootstocks on the growth of 'Gala' apple trees in 2015 (Plot RF185). Trees planted March 2012.

Rootstock	Girth (cm)	Tree volume (m^3)	Pruning weight (g)	Cumulative yield (kg) 2013-15	Yield efficiency (kg/cm^2)
M306-6	10.7*ab*	5.7*b*	288	18.9	2.1
M306-20	11.2*a*	8.1*a*	298	17.5	1.7
M306-79	7.8*c*	3.2*c*	159	15.3	3.3
M306-189	5.1d	1.0*d*	157	7.2	3.7
M9	7.8*c*	2.9*c*	193	12.7	2.7
MM106	9.7*ab*	4.6*bc*	220	17.3	2.2
M116	9.4*bc*	5.6*b*	207	13.2	1.9
SED (16 d.f.)	*0.8*	*0.7*	*107*	*3.9*	*0.5*
Significance	***	***	*ns*	*ns*	*ns*
LSD p=0.05	*1.7*	*2.0*	*227*	*8.2*	*1.6*

*, ** 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 2. The effects of apple rootstocks on the yield of 'Gala' apple trees in 2015 (Plot RF185). Trees planted March 2012.

Rootstock	Mean yield per tree (kg)					Mean number of fruit per tree			
	≥65mm	55-65mm	<55mm	Total		≥65mm	55-65mm	<55mm	Total
M306-6	1.3	12.3	0.4	14		9	122	9	140
M306-20	1.9	11.6	0.3	13.8		13	114	6	132
M306-79	1.3	8.1	0.6	10		9	80	10	99
M306-189	0.3	3.5	1.0	4.8		2	37	15	54
M9	1.1	5.2	0.3	6.6		7	52	5	64
MM106	0.6	10.0	0.9	11.5		2	101	18	121
M116	0.5	9.1	0.4	9.9		4	90	6	100
SED (16 d.f.)	*0.6*	*2.9*	*0.4*	*3.2*		*6*	*30*	*7*	*34*
Significance	*ns*	*ns*	*ns*	*ns*		*ns*	*ns*	*ns*	*ns*
LSD p=0.05	*1.9*	*6.1*	*0.8*	*6.7*		*12*	*63*	*14*	*71*

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

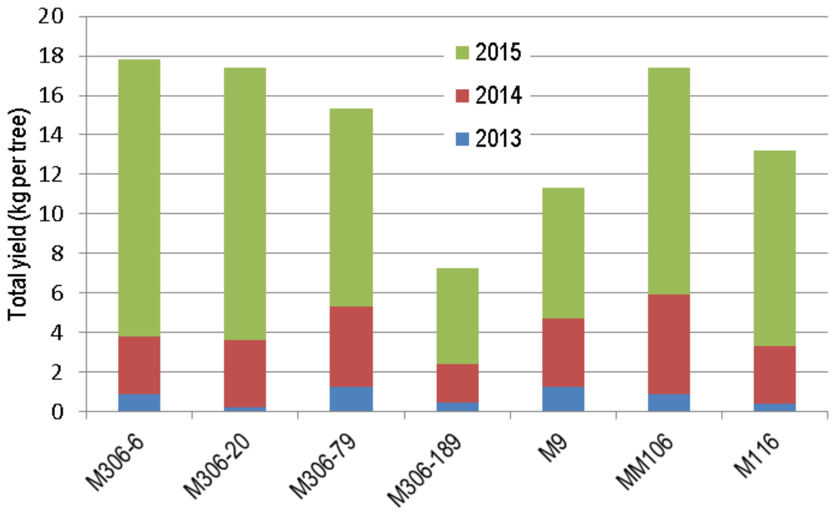

Figure 1. Total annual yields (kg per tree) from M306 series rootstocks and controls, with 'Gala' (Plot RF185) for 2013-15

Pear trial (RF187)

Winter records (height, girth and numbers of suckers) were taken in January 2016, and a summary of this data is shown in Table 3.

In terms of rootstock effect there were significant differences even at this early stage in terms of girth and numbers of suckers, but not any significant effects in terms of height. Two trees on PQ37-3 were found to have died, leaving only two replicates for analysis in the trial. A summary of the performance of each rootstock is shown below:

Table 3. The effects of pear rootstocks on the growth of 'Conference' pear trees in 2015 (Plot RF187). Trees planted August 2014.

Rootstock	Girth (cm)	Height (cm)	Number of suckers
PQ37-2	6.3*a*	16.5	0.3b*c*
PQ37-3	4.4*b*	14.2	0.1*c*
PQ37-5	3.5*b*	11.8	0.0*c*
PQ37-7	5.6*ab*	14	1.5*abc*
PQ37-8	5.4*ab*	13.3	0.0*c*
PQ38-2	4.4*b*	13.5	1.8*ab*
PQ39-1	4.9*a*	14.8	0.8*bc*
PQ39-3	4.3*b*	15.3	2.8*a*
PQ39-4	3.7*b*	14.3	2.5*a*
PQ39-5	6.2*a*	15.5	0.8*bc*
Quince A	5.3*ab*	15.3	0.3*c*
SED (28 d.f.)	*0.8*	*1.5*	*0.6*
Significance	**	*ns*	***
LSD p=0.05	*1.5*	*3.1*	*1.3*

*, ** 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

Second stage trials

Conventional orchard, 'Braeburn' and 'Gala' (EE207)

Five East Malling Rootstock Club selections (AR852-3, AR839-9, B24, R104 and R59) were compared to M9, M26 and M27 under conventional management with 'Braeburn' and 'Gala' as scions. Fruit was harvested in September 2015 and winter records of tree growth and pruning weights were recorded in December 2015 and January 2016 respectively.

Braeburn

Significant differences were found in 2015 for all the parameters measured (Table 4-6), and a summary of the performance of each rootstock is shown below and in Figure 2:

AR852-3 AR852-3 was not as productive in 2015 as it had been in 2014, but was still comparable to M9 (Table 8). Fruit size remained high, with 58% of fruit harvested being >65mm, compared to 25% with M9 and 45% with M26. Yield efficiency was similar to M9 but better than M26, despite the stock exhibiting greater vigour than both M9 (significantly) and M26, with only B24 having a larger tree volume.

AR839-9 This selection was less productive in 2015 than in 2014, with a lower total yield than both M9 and M26. However, the yield of fruit >65mm, average fruit size, cumulative yield and yield efficiency were comparable to M26. Vigour (tree volume) was more similar to M26 than M9. Suckering was more prolific in AR839-9 than with the controls.

B24 As in 2014, B24 had significantly greater vigour (tree volume) than all the other rootstocks with the exception of AR852-3, and the highest pruning weight (Table 8). Yield in 2015 (Table 6) was higher than in previous years (2013 and 2014) and produced fruit of a comparable size to the controls (Table 6). The total cumulative yield was also similar to M26 but the cumulative yield of fruit >65mm was lower, although not significantly so. However, yield efficiency (Table 7) was the lowest of all rootstocks assessed, as in previous years.

R104 This stock exhibited greater vigour (tree volume) than both M26 and M9 but with a similar girth to M26. R104 had the highest total yield in 2015, as it had in 2013 and 2014, significantly higher than for M26 but not M9. In addition it gave the highest cumulative total yield and a relatively high yield efficiency which was again significantly higher than M26 but not for M9. Mean fruit weight in 2015 was similar (ns) to both M26 and M9.

R59 Similar in most respects to M27, with comparable yield (total and cumulative), yield efficiency, tree volume and girth. However it had significantly smaller fruit size than M27 in 2015.

Table 4. Yield and numbers of fruit (means) produced from 'Braeburn' trees (Plot EE207, 2015) on rootstocks planted in 2010.

	Yield (2015)				Mean fruit weight (kg)
	Total (kg/tree)	Total (number/tree)	Class I >65mm	Class I >65mm (number/tree)	
AR852-3	20.6	147.4	12.1	71.6	0.15
AR839-9	12.9	92.9	7.1	41.9	0.14
B24	24.7	199.0	9.0	56.7	0.12
M26	16.8	132.3	7.6	48.0	0.13
M27	9.0	73.2	3.5	19.4	0.13
M9	21.8	184.0	5.5	35.1	0.12
R104	28.2	233.7	8.2	51.7	0.13
R59	8.3	80.7	0.9	5.8	0.09
SED (44 df)	3.5	31.9	2.3	14.0	0.02
Rootstock	***	***	***	***	**

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 5. Cumulative yield and yield efficiency of 'Braeburn' trees (Plot EE207, 2011-2015) on rootstocks planted in 2010.

	Cumulative yield 2010-15 (kg/tree)		Yield efficiency (kg / cm^2)
	Total	Class I >65mm	
AR852-3	44.9	31.5	3.6
AR839-9	25.9	17.4	2.5
B24	34.2	15.3	2.4
M26	32.1	19.1	2.5
M27	22.2	12.3	4.4
M9	41.7	19.8	3.9
R104	53.9	27.3	4.1
R59	22.1	9.2	4.9
SED (44 df)	5.8	3.7	0.7
Rootstock effect*	***	***	**

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 6. Growth measurements (means) of 'Braeburn' trees (Plot EE207, 2015) on rootstocks planted in 2010.

	Girth measurements (cm)	Tree Volume (m^3)	Suckers (No./tree)	Pruning weights (g/tree)
AR852-3	12.7	8.1	0.0	771.0
AR839-9	11.5	5.9	1.5	607.9
B24	13.4	10.7	0.2	1401.3
M26	13.1	6.0	0.1	592.5
M27	7.9	1.8	0.3	307.1
M9	11.3	5.7	0.8	688.8
R104	13.3	7.6	0.2	914.0
R59	7.5	1.3	0.1	64.3
SED (44 df)	0.7	1.2	0.6	231.8
Rootstock effect	***	***	*	***

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

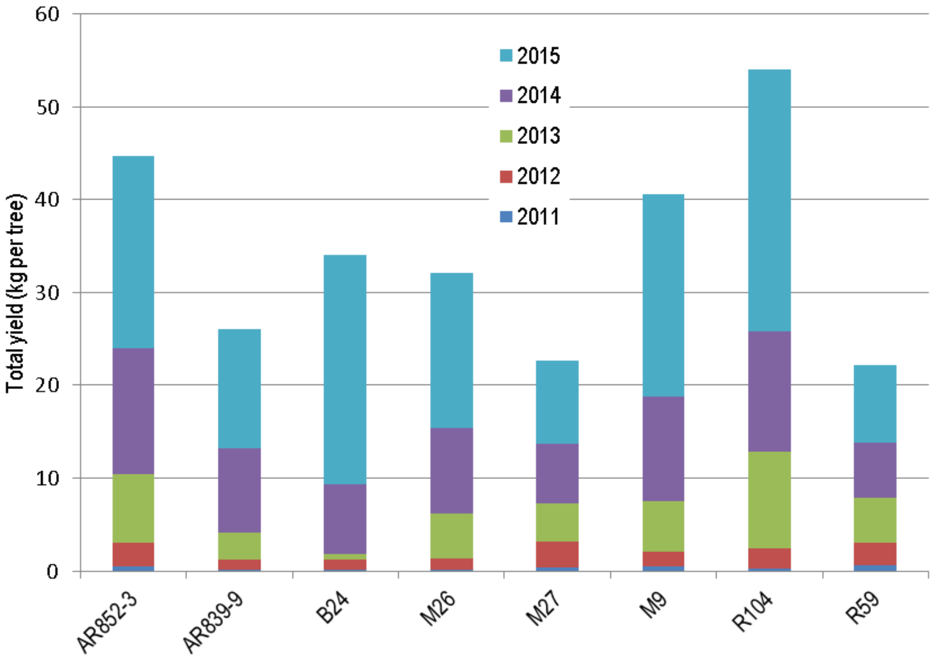

Figure 2. Total annual yields (kg per tree) from five EMRC rootstocks and controls, with 'Braeburn' (Plot EE207) for 2011-15

Gala

Significant differences were found in 2015 for all the parameters measured (Table 7-9), with the exception of mean fruit weight, yield efficiency and the number of suckers per tree. Controls worked with 'Gala' gave a similar performance in terms of total yield as with 'Braeburn' but yielded lower proportion of class 1 fruit. Differences for other genotypes were more pronounced. A summary of the cumulative performance of each rootstock is shown below and in Figure 3:

AR852-3	As with 'Braeburn', AR852-3 gave a comparable total yield to M9 (Table 9) and although average fruit size was good, the proportion >65mm fruit produced was not as high as when grown with a 'Braeburn' scion. Yield efficiency was lower than both M9 and M26 but not significantly so. Vigour was greater (ns) than both M9 and M26, but again not as marked as when grown with a 'Braeburn' scion.
AR839-9	This selection produced a total yield in 2015 that lay between the yields achieved with M9 and M26, but it gave a high proportion of >65mm fruit (31%) and fruit of significantly greater average weight than the controls (c. 9% for M9 and M26). Cumulative yield and yield efficiency were similar to M26 (Table 10). Vigour (tree volume) was most similar to M9.
B24	B24 gave the highest total yield of all the stocks tested in 2015, and gave a cumulative yield slightly higher than M26 (ns) but with a similar Class 1 yield. However, yield efficiency was significantly lower than both M9 and M26 (Table 10) which is attributable to the large tree volume, which was significantly larger than all the other stocks (Table 11).
R104	The high yield produced with 'Braeburn' scion was not repeated with 'Gala', with a total yield in 2015 and cumulative yield comparable to M26. The proportion of fruit >65mm was greater than for M26 in 2015, but this was not reflected in the cumulative data for 2010-15, where the yield of Class 1 fruit size was smaller (Table 10). Yield efficiency was also inferior to both M9 and M26. Vigour lay between M9 and M26 with similar girth measurements to M9.
R59	As with 'Braeburn' R59 was similar in most respects to M27, with comparable yield (total and cumulative), tree volume and girth. However, it had significantly smaller fruit size (mean fruit weight) than M27 in 2015 with a lower (ns) cumulative yield of >65mm fruit. Yield efficiency was shown to be the highest of all stocks tested.

Table 7. Yield and number of fruit (means) produced from 'Gala' trees (Plot EE207, 2015) on rootstocks planted in 2010.

	Yield (2015)				
	Total (kg/tree)	Total (number/tree)	Class I >65mm (kg/tree)	Class I >65mm (number/tree)	Mean fruit weight (kg)
AR852-3	21.8	194.4	6.8	44.6	0.11
AR839-9	18.9	170.2	6.0	38.8	0.12
B24	27.8	262.0	4.5	29.6	0.11
M26	15.9	178.9	1.4	10.3	0.09
M27	7.2	71.4	1.2	8.1	0.11
M9	23.4	251.4	2.1	14.5	0.10
R104	14.8	131.7	3.4	22.8	0.09
R59	8.0	97.0	0.7	4.6	0.09
SED (39 df)	4.1	43.8	1.4	9.0	0.01
Rootstock effect*	***	***	***	***	ns

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 8. Cumulative yield and yield efficiency of 'Gala' trees (Plot EE207, 2011-2015) on rootstocks planted in 2010.

	Cumulative yield 2010-15 (kg/tree)		Yield efficiency (kg / cm²)
	Total	Class I >65mm	
AR852-3	51.6	20.6	4.0
AR839-9	45.1	21.0	4.4
B24	47.4	15.7	2.1
M26	44.1	16.2	4.9
M27	22.3	7.4	3.9
M9	54.8	16.8	4.9
R104	39.0	12.4	2.7
R59	27.2	3.5	5.1
SED (39 df)	7.2	3.5	1.2
Rootstock effect*	***	***	ns

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 9. Growth measurements of 'Gala' trees (Plot EE207, 2015) on rootstocks planted in 2010.

	Girth measurements (cm)	Tree Volume (m^3)	Suckers (No./tree)	Pruning weights (g/tree)
AR852-3	12.7	7.0	0.0	907.1
AR839-9	11.6	6.7	1.4	643.9
B24	15.8	11.6	0.0	1474.0
M26	11.2	5.3	1.3	387.4
M27	8.8	2.9	0.8	132.0
M9	12.5	6.3	0.4	511.4
R104	12.2	5.8	0.4	400.3
R59	8.7	2.5	0.0	60.3
SED (39 df)	1.4	2.1	0.7	244.9
Rootstock effect	***	**	ns	***

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

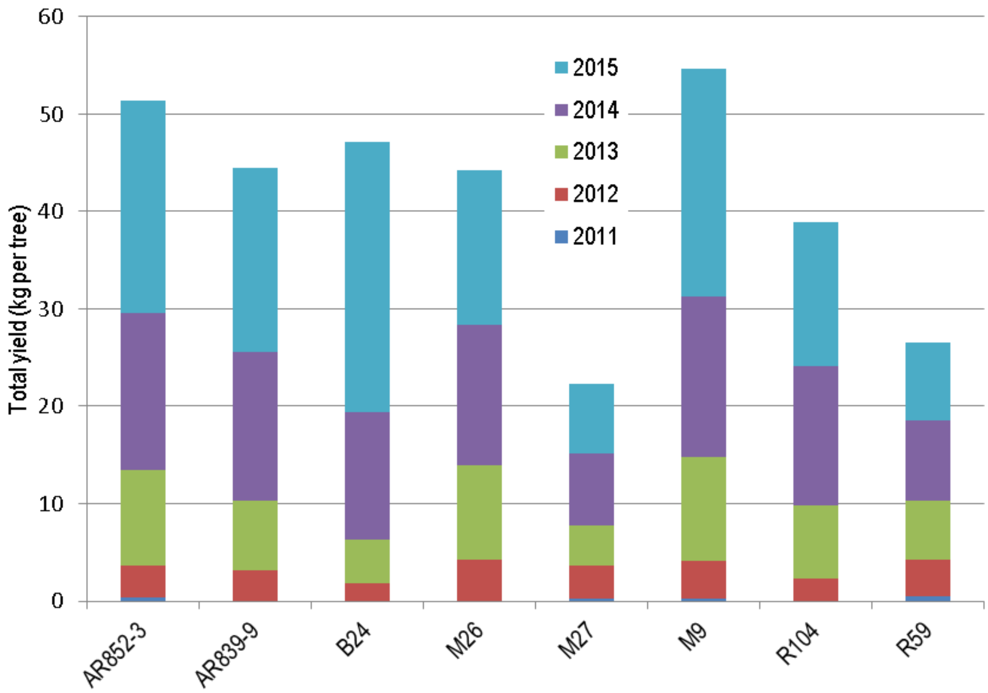

Figure 3. Total annual yield (kg per tree) from five EMRC rootstocks and controls, with 'Gala' (Plot EE207) for 2011-15

Organic orchard, 'Red Falstaff' (VF224)

Four East Malling rootstock club selections (AR10-3-9, AR809-3, AR835-11 and R80) were compared to M116 and MM106 under organic management with Red Falstaff as the scion variety. Fruit was harvested in September 2015 and winter records of tree growth and pruning weights were recorded in December 2015 and January 2016 respectively. Fruit from two trees was judged not to be 'Red Falstaff' and these have now been omitted from the results, including cumulative data from previous years. Figure 4 summarises the yield for different genotypes in this plot.

AR10-3-9	Very similar in every respect to M116, but with a slightly higher yield of fruit >65mm both in 2015 and cumulatively, although this was not significant.
AR809-3	Significantly smaller girth size and tree volume (Table 12) than all the other rootstocks tested which the results of previous years (2012-2014). Although the 2015 total yield for AR809-3 was lower than M116 it did give a comparable yield of >65mmm fruit to both MM106 and M116. This rootstock had a high yield efficiency, with a cumulative yield of fruit >65mm that was also similar to the controls and to R80 (Table 11), but without any apparent detriment to the average fruit size (Table 10). No bitter pit was observed in fruit grown on this stock.
AR835-11	Largest tree volume, significantly greater than all other stocks with the exception of R80 (Table 11). It gave a total yield in 2015 that was comparable to M116 but lower than R80 (ns). Fruit size was large, with 73% of the total yield being in the >65m category and the average overall fruit size (weight) being significantly greater than from M116. Bitter pit was noted in 5% of fruit.
R80	Produced the highest total yield in 2015 (Table 10), as it had in 2014, and which was significantly higher than AR809-3 and MM106. This high yield was mirrored in its cumulative yield (Table 11) which was significantly higher than all the other stocks in the trial. However this was combined with a large tree volume (Table 12) which was significantly larger than MM106, and only surpassed in volume by AR835-11. Bitter pit was noted in 5% of fruit.

Table 10. Yield and number of fruit produced from 'Red Falstaff' trees (Plot VF224, 2015) on rootstocks planted in 2010.

	Yield 2015 (kg/tree)	Yield 2015 (number/tree)	Yield Class I >65mm 2015 (kg/tree)	Yield Class I >65mm 2015 (number/tree)	Mean individual fruit weight (kg)
AR10-3-9	4.8ab	51.0	1.6	11.0	0.10
AR809-3	2.3c	19.9	1.3	8.8	0.12
AR835-11	4.5ab	35.4	3.3	21.5	0.13
M116	4.5ab	58.5	1.5	10.5	0.09
MM106	3.4bc	31.6	1.6	11.2	0.12
R80	5.7a	66.9	2.2	15.6	0.10
SED (32 df)	1.0	12.3	0.6	4.2	0.01
Rootstock effect	*	**	*	ns	*

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 11. Cumulative yield and yield efficiency of 'Red Falstaff' trees (Plot VF224, 2011-2015) on rootstocks planted in 2010.

	Cumulative yield 2011-15(kg/tree)		Yield efficiency (kg / cm^2)
	Total	Class I >65mm	
AR10-3-9	8.6b	3.3	0.3
AR809-3	5.6b	2.5	0.6
AR835-11	7.7b	4.7	0.3
M116	8.6b	2.7	0.3
MM106	8.3b	3.5	0.4
R80	13.0a	4.8	0.7
SED (32 df)	1.8	1.0	0.1
Rootstock effect	**	ns	**

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

Table 12. Growth measurements on 'Red Falstaff' trees (Plot VF224) on rootstocks planted in 2010.

	Girth measurements (cm)	Tree Volume (m^3)	Suckers (No./tree)	Pruning weights (g/tree)
AR10-3-9	12.6	4.9ab	0	327
AR809-3	8.8	1.7c	0	46
AR835-11	12.1	8.7a	0	237
M116	13.0	4.7ab	0	182
MM106	11.8	4.2b	0	162
R80	11.6	6.7a	0.1	188
SED (32 df)	0.7	1.0	0.1	96
Rootstock effect	***	***	ns	ns

*rootstock effect was either non-significant (ns) or significant at the 5 (*), 1 (**) or 0.1% (***) level of probability

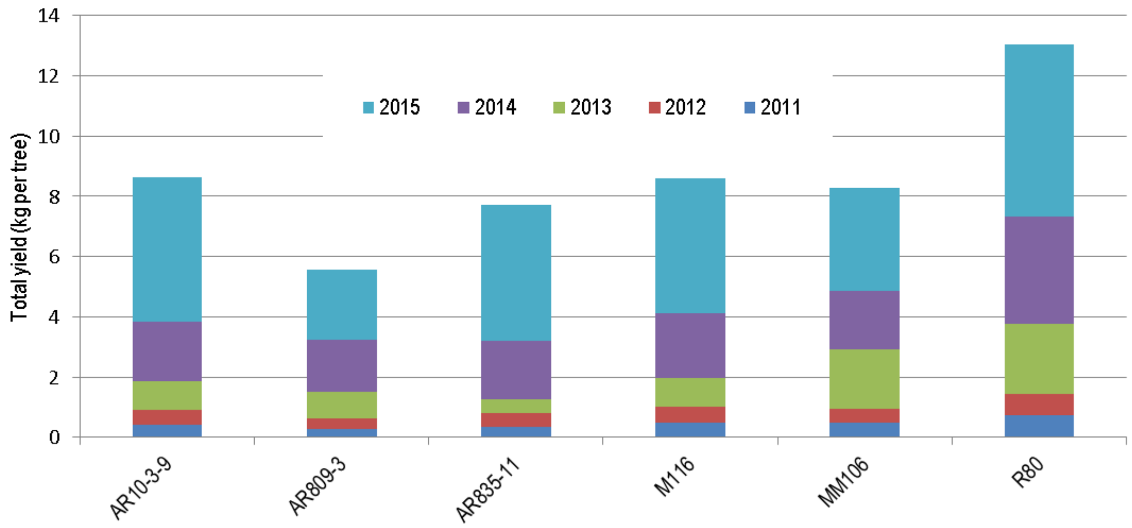

Figure 4. Total annual yields (kg per tree) from five EMRC rootstocks and controls, with 'Red Falstaff' (Plot VF224) for 2011-15

Newly planted conventional apple trial – Canadian rootstocks (SP250):

Genotyping of material planted to verify trueness-to-type:

Using material introduced directly from the breeders in Canada, we verified 'trueness to type' of the liners provided by FPM in 2014-15 (as UK nursery reference) and maintained in pots at EMR as well as the material planted in the trial. All genotypes included in the trial, match the breeders reference and the UK reference. References for two accessions that are not included in the trial (due to insufficient take) were also provided. We have identified a discrepancy between the UK stock and the Canadian source material for one of them but this does not affect the trial.

As mentioned in previous reports, each individual tree in the trial was tested in 2014-15 to ensure trueness-to-type (TTT). This winter, we completed this testing repeating the samples that failed in the first analysis for which fresh material was collected. Additionally, a visual inspection of the scions in autumn 2015 highlighted some potential mislabelling between 'Braeburn' and 'Gala'. Leaf samples were collected and DNA tests performed to confirm the scion variety in fourteen trees.

Out of 198 trees (including those in guard rows), 20 individual rootstocks were not true-to-type; eight scions have been mislabelled and one tree was wrongly labelled for both scion and the rootstock (Figure 5; Table 13) resulting in an unbalance experimental design. The modified plot plan (Figure 5) was submitted to our statistician who advised regression analysis to calculate estimated mean values. ANOVA will be used to determine pairwise significant differences.

Tree	Row A	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row B
X	G	G	G	G	G	G	G	G	G
1	G	11	17	16	15	1	7	13	G
2	G	5	10	20	9	14	4	12	G
3	G	6	8	3	19	18	2	7	G
4	G	16	15	6	11	20	18	17	G
5	G	1	12	14	8	4	3	2	G
6	G	9	13	5	3	19	3	11	G
7	G	3	20	10	14	15	6	4	G
8	G	18	5	8	14	3	17	9	G
9	G	7	19	12	6	10	19	1	G
10	G	17	4	11	10	16	15	3	G
11	G	14	9	3	11	2	20	6	G
12	G	8	8	18	2	17	5	10	G
13	G	12	16	9	5	8	3	19	G
14	G	4	11	2	2	7	14	15	G
15	G	3	14	17	6	6	10	8	G
16	G	20	2	1	10	11	9	19	G
17	G	15	12	7	18	13	12	5	G
18	G	19	13	15	17	5	11	18	G
19	G	10	1	19	7	12	16	14	G
20	G	2	6	4	11	9	8	20	G
Y	G	G	G	G	G	G	G	G	G

Rootstock NTTT Scion NTTT R/S & Scion NTTT

Figure 5. Final plot plan for apple rootstock trial SP205. Guard trees (G) are shaded in purple. Trees not true to type (NTTT) with respect to the original plot plan are shaded in orange (incorrect rootstock), green (incorrect scion) or yellow (both scion and rootstock are incorrect).

Table 13. Number of trees of each rootstock/scion combination planted vs those originally planned.

Treatment	Rootstock	Variety	# trees planted SP250	
			Planned	TTT
1	M9	Braeburn	7	5
2	M26	Braeburn	7	8
3	M27	Braeburn	7	10
4	MM106	Braeburn	7	6
5	SJM127	Braeburn	7	7
6	SJM167	Braeburn	7	8
7	SJM188	Braeburn	7	6
8	SJP84-5217	Braeburn	7	8
9	SJP84-5162	Braeburn	7	7
10	SJP84-5174	Braeburn	7	8
11	M9	Gala	7	9
12	M26	Gala	7	7
13	M27	Gala	7	4
14	MM106	Gala	7	8
15	SJM15	Gala	7	7
16	SJM167	Gala	7	5
17	SJM189	Gala	7	7
18	SJP84-5217	Gala	7	6
19	SJP84-5231	Gala	7	8
20	SJP84-5174	Gala	7	6

Field evaluation:

Winter records (height, girth and numbers of suckers) were taken in January 2016, and a summary of this data is shown in Tables 14 and 15. As the trial design was unbalanced due to variable number of trees available pre-planting and trueness-to-type problems identified post-planting, regression analysis was used to give estimated mean values but no single SED can be attributed for all rootstock comparisons. However, ANOVA on the regressed data indicates significant differences across the data, with significance noted in pairwise comparisons between rootstocks.

Braeburn

For girth and height measurements, the only rootstock that was significantly different from M9 was M27 which was significantly smaller for both traits ($p>0.001$). SJP184-5117 was the most invigorating rootstock in the trial, producing trees that were significantly taller than both M27 ($p<0.001$) and M26 ($P<0.01$), but not M9.

Gala

For girth measurements, the only rootstocks that were significantly different from M9 were the standards, M27 ($p<0.001$) and M26 ($p<0.05$) that were smaller and larger respectively. Significant differences in tree height were found between M27 and both M26 ($P<0.01$) and MM106 ($p<0.05$), but not with M9. 'Gala' on SJM15, SJM189 and SJP184-5231 had a similar (ns) height to those on M27 which was evident with 'Braeburn'. SJP184-5217 was the most invigorating of the rootstocks, giving a significantly taller tree than all of the other rootstocks except MM106, as was noted with 'Braeburn'.

Table 14. The effects of apple rootstocks on the growth of 'Braeburn' apple trees in 2015 (Plot RF187), estimated mean values based on regression analysis. Trees planted 2014.

Rootstock	Girth (cm)	Height (cm)	Number of suckers
SJM127	6.9	16.3	0.2
SJM167	6.7	16.7	0.0
SJM188	6.1	15.7	0.0
SJP184-5217	7.1	17.6	0.0
SJP184-5162	6.0	16.8	0.0
SJP184-5174	6.3	16.0	0.0
M9	6.6	16.5	0.0
M26	6.2	15.7	0.1
M27	5.0	12.4	0.3
MM106	6.8	16.5	0.1

Table 15. The effects of apple rootstocks on the growth of 'Gala' apple trees in 2015 (Plot RF187) estimated mean values based on regression analysis. Trees planted 2014.

Rootstock	Girth (cm)	Height (cm)	Number of suckers
SJM15	5.8	14.5	0.1
SJM167	6.9	15.8	0.0
SJM189	6.4	14.8	0.0
SJP184-5217	6.7	17.5	0.0
SJP184-5231	6.2	14.2	0.0
SJP184-5174	6.4	15.4	0.4
M9	6.2	15.0	0.1
M26	7.0	15.4	0.0
M27	4.8	14.0	0.0
MM106	6.6	16.3	0.2

Breeding activities

Crossing and germination

Crosses were made from mid to late April until early May and fruit set was generally good. Seeds were extracted in October with generally good results except for the pear cross with Pyronia as a pollen donor.

In total 6,300 apple seeds were produced in 2015 and 3,508 from eight different crosses were sown in December (Table 16). This included stored seeds for two families (M595 and M596). Seed was retained for four as yet unnamed families. For three of them, the crosses will be repeated in 2016 and seed accumulated for a more meaningful family size. More than 1,000 from a cross between M.M.106 x M.27 were also stored for possible use in future research projects (originally for unsuccessful rooting proposal). Back-up seed from families M597 and M598 was also kept as a precaution in case of poor crossing success in future seasons.

For pears, 532 seed were produced in 2015 from three different crosses (Table 17). A fourth cross using diploid 'Pyronia' as a mother was unsuccessful. No pear population was raised in 2016 so these seed will be stored for germination in 2016-17 and family numbers will be assigned at this point.

In total, 3,508 apple seeds were sown in early December 2015 and stratified at 2°C for 14 weeks. In March 2016, they were transferred to a heated glasshouse (Day Tm > 18 °C, Night Tm >15°C) with supplementary lighting, as needed for 16h day light. Average germination (Table 16) was just under 52% but great differences could be seen between families; for M600 and M602 over 90% of seed germinated whereas M599 was particularly disappointing (24%). M597 (expected to segregate for two fire-blight resistance genes) has been chosen to test the feasibility of marker assisted seedling selection (MASS) in 2016. We do not expect to plant the majority of these seedlings.

Table 16. Results from the apple rootstock crossing in 2015 and preliminary germination results.

Family	Year of Cross	Cross	# of flowers	# of fruit	# of seeds		germinated	
		Female x Male			produced	sown	#	%
M595	2014	A469-4 x MH.12.3			2	143	87	61
	_2015_	A469-4 x MH.12.3	108	44	141			
M596	2014	M.13 x Bud.9			69	384	291	76
	_2015_	M.13 x Bud.9	340	73	315			
M597	2015	Evereste x C.G.202	540	429	1,643	1,000	650*	65
M598	2015	Evereste x AR295-6	425	341	1,577	500	440	88
M599	2015	Novole x AR295-6	319	255	495	495	120	24
M600	2015	Bud 9 x Evereste	352	196	462	504	460	91
M601	2015	M.116 x AR295-6	83	33	255	255	218	85
M602	2015	M.13 x C.G. 11	325	40	227	227	206	91
	2015	M.13 x AR295-6	321	13	36	Stored; repeat cross 2016		
	2015	C.G. 11 x AR295-6	90	8	27	Stored; repeat cross 2017		
	2015	AR295-6 x C.G.30	379	48	88	Stored; repeat cross 2018		
	2015	M.M.106 x M.27	340	185	1034	Genetic studies only		
		Total	**3,622**	**1,665**	**6,300**	**3,508**	**1,822**	**52**

*Population for MASS.

Table 17. Results from the pear rootstock crossing in 2015.

Cross			# of flowers	# of fruits	# of seeds
Female	**x**	**Male**			
OH x F69	x	B12	261	14	69
Old Home	x	B14	256	38	227
OH x F51	x	Pyronia (x2)	330	49	236
Pyronia (x2)	x	OH x F51	187	9	-
		Total	**1,034**	**110**	**532**

New seedling populations

Apple

A total of 1,342 new apple seedlings from eight different families (Table 18) were planted in August 2015 through mypex in double rows (Figure 1) to be budded in August 2016 with 'SA544-28' columnar scion for further field evaluation. Control rootstock varieties for this plot were grafted in February 2016 to be planted out in the autumn.

Table 18. Apple rootstock seedlings planted in 2015

Family	Cross	Year of crossing	Planted (Aug 2015)
M587	Geneva 202 x AR295-6	2014	**64**
M588	AR295-6 x Geneva 202	2014	**64**
M589	Evereste x Geneva 30	2014	**742**
M590	M.13 F x M.116	2014	**14**
M591	M.M.106 x Geneva 30	2014	**95**
M592	Geneva 30 x M.27	2014	**248**
M593	Bud.9 x Evereste	2014	**69**
M594	Novole x M.116	2014	**46**

Figure 6. Apple seedling plot, planted through mypex in August 2015

Pear

A total of 406 new pear seedlings from five different families (Table 19) were planted in August 2015 also through mypex in double rows and surviving seedlings will be budded with ‘Concorde’ in August 2016. Control rootstock genotypes for this plot will be procured and planted up as for the apple plot.

Table 19. Pear rootstock seedlings planted in 2015

Family	Cross	Year of crossing	Planted (Aug 2015)
PRP51a	OHxF87 x P525-3	2013	**103**
PRP53	OHxF333 x BP1	2013	**83**
PRP54	OHxF51 x Pyronia (x2)	2014	**32**
PRP55	Old Home x BP3	2014	**15**
PRP56	P298-18 x P. serotina ‘Kumloi’	2014	**173**

Evaluation of existing seedling populations

Apple

Eleven families (listed below) were assessed by breeders in September/ October 2015. Records on vigour, crop load and suckering were taken as appropriate and, in certain genotypes, fruit size and other traits suck as burrknot production or woolly apple aphid colonization were also noted.

- M553 (AR86-1-20 x Geneva 202)
- M554 (M.M.106 x Geneva 30)
- M555 (Geneva 30 o.p.)
- M556 (Ottawa 3 o.p.)
- M557 (M.116 x M.9)
- M558 (Geneva 30 x M.116)
- M559 (Bud 9 x M.9)
- M560 (AR86-1-20 x Geneva 11)
- M561 (M.27 x Geneva 30)
- M562 (M.M.106 x Geneva 202)
- M563 (M.M.106 x Bud 9)

Some preliminary elections were made from families M553 (six selections), M554 (four selections) M555 (six selections) and M556 (one selection), details of which are shown in Table 20. However, as take from budding in these families was initially very poor, around half the individuals in each family were re-budded a year later. To avoid selections from the same families to fall into two propagation schedules, these preliminary selections will be recorded again in 2016 and, if retained, propagated with any additional selections made in 2016 from the remaining seedlings.

Pear

Six pear families were also assessed in September 2015 but none were deem sufficiently mature for selections to be made. Records were taken on vigour; suckering and crop load.

- 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)

Table 20. Apple seedling preliminarily selected in summer/autumn 2015

Plot	Selection	Vigour			Crop load*			Suckering		
		2013	2014	2015	2013	2014	2015	2013	2014	2015
SC198	**M553-2**	mw	mw	mw	-	h	h	++	+	+
SC198	**M553-52**	w	w	w	-	0	0	++	++	++
SC198	**M553-64**	mv	m	mw	-	0	m	-	+	+
SC198	**M553-65**	m	m	m	-	l	m	+	+	-
SC198	**M553-107**	mv	mw	m	-	l	mh	++	++	+++
SC198	**M553-112**	mw	w	mv	-	vl	m	+	-	-
SC198	**M554-17**	w	mw	m	-	0	mh	-	-	-
SC198	**M554-92**	m	mv	mv-m	-	l	m	-	+	+
SC198	**M554-215**	m	vw	w	-	0	mh	++	+++	++
SC198	**M554-324**	m	m	m	-	l	l	++	++	++
SC198	**M555-30**	m	mw	mv	-	0	m	+	-	+
SC198	**M555-60**	m	mw	mw-w	-	l	m	+	+	-
SC198	**M555-85**	mw	mw	mw	-	0	mh	-	-	-
SC198	**M555-131**	mw	mw	m	-	0	h	+	-	+
SC198	**M555-221**	mw	w	mv	-	0	mh	+	++	+
SC198	**M555-243**	mw	w	mw	-	0	h	+	+	++
SC198	**M556-46**	m	m	mv	-	0	vh	+	+	+

* vw = very weak, w = weak, mw = medium to weak, m = medium, mv= medium to vigorous, v= vigorous

† - = not recorded; 0 = no crop, vl = very light, l = light, m= medium, mh= medium to heavy, h= heavy, vh= very heavy

‡ scale of suckers observed: - = no suckers, + = 1 or 2 small suckers, ++ = several small or few large suckers, +++ = many suckers

Pest and disease resistance screening

Fire-blight (FB)

Four EMR advanced selections (Table 21) were tested in 2015 at Agroscope (CH). Only AR440-1 had not previously been tested but the result for the other three selections were either variable or intermediate, requiring verification. Graftwood from these genotypes and two control cultivars were sent to Wädenswil in January for inoculation and monitoring by Markus Kellerhals's team.

Table 21. Apple genotypes to be tested for 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 M.9	Possibly intermediate	12
AR839-9	M.7 x M.27	Possibly intermediate	12
AR440-1	M.25 x M.27	Not tested	12
CG-935	Ottawa 3 x *M. robusta* 5	Resistant	12
M.9	Unknown	Susceptible	12

According to the protocol described in the methods section, material tested could be classified (Figure 7) with regards to its response to Fireblight by measuring the percentage of lesion developed in shoots following inoculation in comparison with the susceptible control ('Gala Galaxy'). The results from this test were received in July 2015. Figure 7 shows the evolution of the disease following inoculation and Figure 8 the final lesion levels in order of ascending susceptibility.

resistant	lesion length (%LL3)	< 5%	compared to %LL3 from 'Gala Galaxy'
very low	lesion length (%LL3)	5-25%	compared to %LL3 from 'Gala Galaxy'
low	lesion length (%LL3)	25 - 40%	compared to %LL3 from 'Gala Galaxy'
medium	lesion length (%LL3)	40 - 25%	compared to %LL3 from 'Gala Galaxy'
high	lesion length (%LL3)	60 - 100%	compared to %LL3 from 'Gala Galaxy'
very high	lesion length (%LL3)	> 100 %	compared to %LL3 from 'Gala Galaxy'

Figure 6. Classification of fireblight susceptibility following inoculation at Agroscope (CH).

In this test, AR295-6 was found to show very low susceptibility (15% PLL3/GGPLL3), AR835-11and AR839-9 were found to show low susceptibility (27% and 29% PLL3/GGPLL3) whereas AR440-1 was found highly susceptible (70% PLL3/GGPLL3). In Table 22, we summarised the results accumulated in three years of testing.

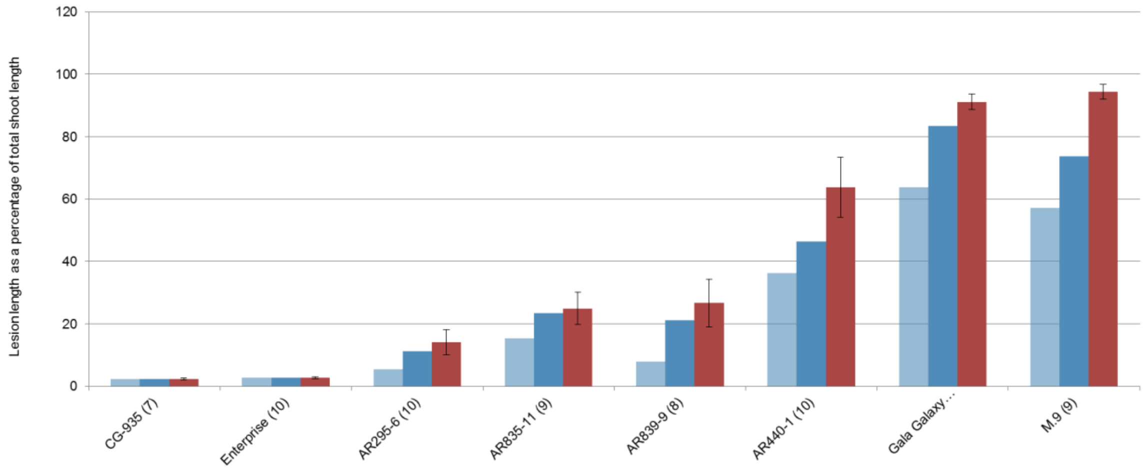

Figure 7. Lesion length as a percentage of total shoot length of eight apple genotypes measured 7, 14 and 21 days after inoculation with *Erwinia amylovora* (strain FAW610Rif at 109 cfu/ml^{-1})

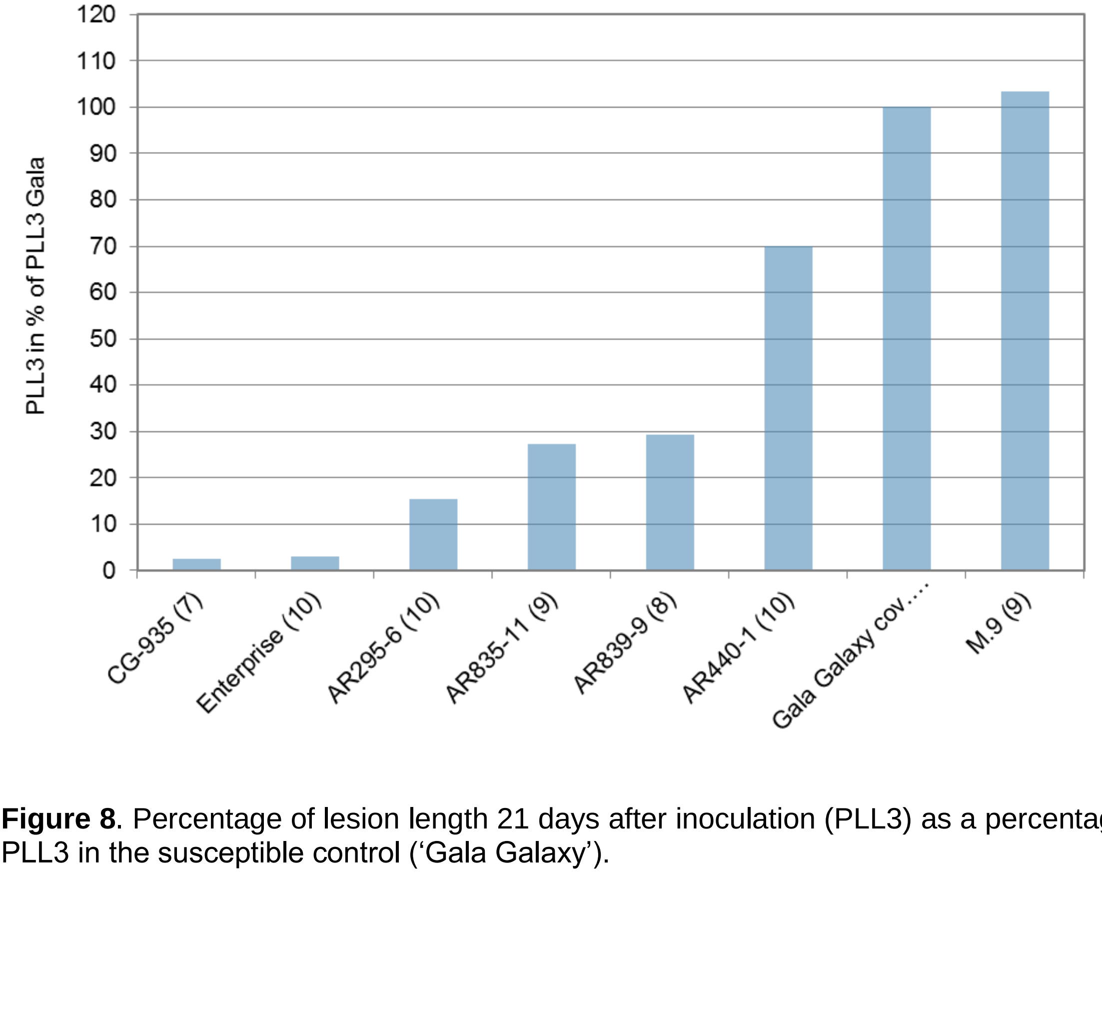

Figure 8. Percentage of lesion length 21 days after inoculation (PLL3) as a percentage of PLL3 in the susceptible control (‘Gala Galaxy’).

Table 22. Summary of fire blight (FB) resistance screening for EMR rootstock genotypes following repeated inoculation with *Erwinia amylovora* isolates 'Ea782', 'Ea797' and 'Ea914' in 2012 and 'Ea797', 'Ea839' and 'Ea951' in 2013 (both in Germany) and after single inoculation with 'Ea FAW610 Rif' in 2015 (Agroscope, CH).

Genotype	2012			2013			2015 test		Susceptibility score
		% of necrosis			% of necrosis		Agroscope		
	Reps	Range	Average	Reps	Range	Average	Reps	%PLL3+	
AR10-2-5				9	55-100	87			High
AR10-3-9	7	47- 100	78	6	60 - 86	66.2			High
AR295-6				7	3 - 25	10	10	15%	Very low
AR440-1							10	70%	High
AR680-2				6	65 - 100	82			High
AR809-3	8	17 - 100	74						High
AR835-11	5	4 - 95	53	7	21 - 84	41.7	9	27%	Low
AR837-19				10	18 - 74	44.4			Low-Medium?
AR839-9	8	2 - 100	41	1	n.a.	28.6	9	29%	Low
AR852-3	5	47 - 100	80						High?
B24	4	21- 100	73						Medium-High?
R104	4	53 - 100	77						High?
R59	8	58 - 100	84						High?
R80	6	19 - 100	68						Medium-High?
CG-935							7	2%	Resistant
M.9 T337	7	19 -100	69	6	16-100	47.5		102%	Very high
Supporter 4				5	53 - 89	69.1			
				* all except one < 50%			+ vs. Gala Galaxy		

Phytophthora cactorum

A request to UK growers for sources of inoculum in 2014 resulted in three isolates being collected and analysed by pathologists at EMR (cultured through apple). Only two of those isolates grew well in culture and they were used to produce inoculum for this experiment.

The potted trees of the 13 genotypes used in last year's experiment (M116, CG-16, AR839-9, M27, CG-202, CG-935, AR295-6, CG-41, CG-11, M26, M25, Pajam 2), were overwintered in a sand bed, moved into a glasshouse with temperature control in early spring and set up in the same layout as in 2014 with one un-inoculated control and three infected replicates.

Three successive inoculations were carried out using zoospore suspensions and trees were stressed by an alternation of over- and under-watering. Most trees continue to grow well and showed no symptom in the first month. After approximately eight weeks, several trees including all the AR295-6 replicates (including non-inoculated) started to loose leaves and died but they showed no clear symptoms of Phytophthora infection and the pathogen could not be recovered from these plants.

After these two attempts we have come to the conclusion that pot inoculation of liners or well established hard wood cuttings in pots in unlikely to be useful for large scale testing and lacks the reliability of the seedling test and it is very expensive to carry out as the trees need to be maintained in a chilled glasshouse for a long period in the summer.

The next step will be to try and create a more comparable test to the seedling inoculation using young soft wood cuttings in their rooting trays. As a preliminary test, cuttings of each of the 13 genotypes were taken in August 2015 and set up to root under mist. Although root initiation in most genotypes was encouraging to begin with, numbers were insufficient to repeat a test. Also, softwood cuttings were considered too immature to provide a reliable test by the members of the EMRC steering committee in their September 2015 meeting, thus this plan was abandoned.

In 2016, we will aim to determine the virulence on the inoculum in recently germinated seedlings and attempt to inoculate hardwood cuttings for replicated tests.

Apple Replant Disease (ARD)

The majority of work currently carried out at NIAB EMR is part of ARDERI project (HaPI II; BBSRC 2015-2018). The industry collaborators for this project are not the same as those in the EMRC but some of it findings will support the characterisation of AR295-6 in replant scenarios following M.M.106 and M.9 orchards. This project looks at changes in soil microbiome (fungi, oomycetes, bacteria, and nematodes) in relation to the rootstock genotype present in the soil using metagenomics analysis over time. Relevant findings from this project will be communicated to AHDB as appropriate.

Additionally, we are in the process of establishing a replant trial for our advance selections and commonly used germplasm. Between 9 and 12 rootstock liners of 22 rootstock genotypes (Table 23) were budded with a columnar scion in February 2015. The original plan was to set up tree replicates of each genotype in a) virgin soil, b) replant soil (untreated) and c) replant soil treated with chloropicrin in 2014. Unfortunately, grafting take and survival was not very good and for many of the EM selection there were not enough trees. Instead, we decided to save the virgin land (as it is very rare) and set up a smaller treated vs untreated test with four replicates (Figure 9) with all the genotypes with seven or more available trees. Trees were all tipped at a maximum of 50 cm from the graft union; height at planting and girth at 10 cm from graft were recorded and soil samples for each planting hole taken. Roots were also sampled for DNA verification of each rootstock genotype. Phenotyping for symptoms and soil sampling will be carried out in collaboration with the ARDERI project.

Table 23. Genotypes grafted with columnar scion in February 2015 for Apple Replant Disease (ARD) trial plot and number of successful grafts available.

Source	Rootstock	Parentage	Reported ARD	Available
Dalicom	**CG-11**	M. 26 x M. robusta 5	Susceptible	4
Dalicom	**CG-16**	Ottawa 3 x M. floribunda	Partial tolerance	10
Dalicom	**CG-202**	M.27 x M. robusta 5	Tolerance	1
Dalicom	**CG-41**	M.27 x M. robusta 5	Tolerance	2
Dalicom	**CG-935**	Ottawa 3 x M. robusta 5	Tolerance	4
IFO	**AR10-2-5**	M.M.106 x M.27	TBD	8
IFO	**AR10-3-9**	M.M.106 x M.27	TBD	4
IFO	**AR440-1**	M.25 x M.27	TBD	7
IFO	**AR486-1**	Ottawa 3 x M.7	TBD	4
IFO	**AR628-2**	Ottawa 3 x M.M.106	TBD	7
IFO	**AR680-2**	M.26 x M.7	TBD	7
IFO	**AR835-11**	M.I.793 x M.9a	TBD	8
IFO	**AR837-19**	M.3 x M.1	TBD	7
IFO	**AR839-9**	M.7 x M.27	TBD	5
IFO	**AR86-1-20**	M.M.106 x M.27	TBD	2
FP Matthews	**M116**	M.M.106 x M.27	Tolerance TBC	4
FP Matthews	**M25**	Northern Spy x M.2	Tolerance TBC	10
FP Matthews	**M26**	M.16 x M.9	Susceptible	9
FP Matthews	**M27**	M.13 x M.9	TBD	11
FP Matthews	**M9**	Unknown	Susceptible	9
FP Matthews	**MM106**	Northern Spy x M.1	Partial tolerance	13
IFO	**AR295-6**	M. robusta 5J x Ottawa 3	TBD	16

N

Tree/Row	GE191 1	GE191 2	GE191 3	GE191 4	GE190 1	GE190 2	GE190 3	GE190 4
13	6	11	12	5	3	11	2	3
12	2	**10**	4	4	10	8	7	6
11	11	5	7	**13**	1	6	4	5
10	7	9	10	9	5	1	8	12
9	**9**	12	5	3	11	2	6	1
8	10	1	8	8	9	7	5	8
7	13	7	2	11	2	3	1	11
6	3	8	1	1	6	12	11	2
5	8	2	13	2	8	10	13	4
4	12	3	3	7	7	5	12	7
3	1	4	**11**	6	12	4	3	9
2	5	13	6	12	4	13	10	10
1	4	6	9	10	13	9	9	13

#	Rootstock	Parentage	Available
1	M.9	Unknown	9
2	M.25	Northern Spy x M.2	10
3	M.26	M.16 x M.9	9
4	M.27	M.13 x M.9	11
5	M.M.106	Northern Spy x M.1	13
6	CG-16	Ottawa 3 x *M. floribunda*	10
7	AR10-2-5	M.M.106 x M.27	8
8	AR295-6	*M. robusta 5* x Ottawa 3	16
9	AR440-1	M.25 x M.27	7
10	AR628-2	Ottawa 3 x M.M.106	7
11	AR680-2	M.26 x M.7	7
12	AR835-11	M.I.793 x M.9	8
13	AR837-19	M.3 x M.1	7

Figure 9. Experimental design for ARD test plot at East Malling

Woolly apple aphid (WAA)

As in previous years, aphid populations were overwintered in the nursery and seemed to be thriving at the beginning of the season. However, during the 2015 summer colony establishment was far from ideal with a number known susceptible cultivars and genotypes previously colonized showing only very slight symptoms by the middle of October. For this reason, we are only considering conclusive results indicating clear susceptibility as for the following genotypes: AR10-3-9, AR295-6, AR69-7, AR809-3, M9 (Pajam 2), M482-13, M482-158, M482-175, M482-49, M482-54, M482-87 and M546-125). Unclear genotypes will be re-tested in 2016.

Knowledge and Technology Transfer

EMRC management committee meeting – East Malling, September 2015

EMRC management committee meeting – East Malling, January 2016'

Rootstocks in the making' – Project Profile (Tree Fruit Review 2016; AHDB Horticulture)

