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Date project completed (or expected completion date):	31st March 2012 (extendable until 31st March 2014)

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.

Ms Felicidad Fernández
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Programme Leader
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GROWER SUMMARY

Headline

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

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. There are few breeding programmes worldwide 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 M (Malling) and MM (Malling-Merton in collaboration with the then 'John Innes Horticultural Institution') apple rootstocks. As a consequence of the reduction in government funding for 'near-market' research in the 1990's, industry support for the programme was sought and between 1992 and 2007, breeding apple and pear rootstocks formed one of the objectives of the East Malling Apple and Pear Breeding Club (APBC). The Apple and Pear Research Council and more recently the Horticultural Development Company (HDC) were the UK Licensees for the material developed as part of the APBC, which included two new rootstock releases, M116 for apple and EMH, a quince rootstock for pear.

In 2008, EMR, the HDC 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.

EMR has a wealth of breeding lines, derived from, UK, USA, Canadian and Japanese material, encompassing diverse agronomic variation and a wide range of resistance to various pests and diseases. Defra continues to fund underpinning strategic research at EMR on genetic mapping of rootstocks and the development of molecular markers for pre-selection of key rootstock characters. The programme is strengthened by EMR's diverse collaborators and international contacts.

For UK growers, the HDC also acts as the UK licensee for the East Malling Rootstock Club

(EMRC) with the intention of making new rootstocks released from EMR's programme, widely available to UK levy payers. The HDC 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.

It can take over 30 years to develop a new rootstock. Selection of parental material, crossing, seedling selection and first stage trialling are carried out at EMR, and take around 10 years. Promising material is then propagated and released for HDC-funded trials in the UK and INN-funded trials at appropriate sites around the rest of the world. As trial results accumulate and the most promising selections are validated , the rootstocks are propagated to build up sufficient material for distribution before it is possible to co-ordinate effective world-wide release.

The EMRC is completing the evaluation of apple, pear and quince rootstock material developed by the former APBC that is currently in the pipeline, with the aim of identifying a range of apple, pear and quince rootstocks with desirable size control, precocity and productivity, with resistance to diseases and pests where applicable. New breeding material is being produced, taking account of potential climate change scenarios, using a new streamlined system previously developed in an associated project funded by the Department for the Environment, Food and Rural Affairs (Defra).

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

Currently, there are 40 pear selections at different stages of evaluation. Nine apple selections from the EMRC programme have been included in the latest HDC-funded trial planted in February 2010. A further 11 apple and five pear progenies are currently at different stages in the selection pipeline. Progress to date:

- Fifteen apple and eight pear selections have entered propagation for preliminary trials.
- A further seven apple seedlings were identified as interesting and cut back for propagation in 2011-12.
- Twenty new progenies (14 apple and six pear) have been raised thus far.
- Six new crosses (four for apple and two for pear) were carried out in spring 2011.

Financial benefits

- Financial benefits to the UK industry will arise once new rootstocks from the programme are released.

Action points for growers

- There are no action points for growers at this stage in the project.

East Malling Rootstock Club annual report 2011-12

SCIENCE SECTION

Background

Improved rootstocks are essential for profitable and sustainable production of 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 then John Innes Horticultural Institution).

In 2008 EMR, the HDC 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.

On behalf of UK growers the HDC 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. The HDC 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 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 can take over 30 years to develop a new rootstock. Selection of parental material, crossing, seedling selection and first stage trialling (which are carried out at EMR) all takes around 10 years. Promising material is then propagated and released for HDC-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 is also completing the evaluation of apple, pear and quince rootstock material developed by the former APBC and currently still in the pipeline. New breeding material is also being produced, taking account of potential climate change scenarios, using a new streamlined system previously developed in an associated project funded by the Department for the Environment, Food and Rural Affairs (Defra).

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

Method

The breeding programme in an on-going effort, the different steps of which are briefly described below:

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 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 at the 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 2 - 3 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 standard rootstocks are interspersed in the seedling population as controls. Rootstocks ‘M27’, ‘M9’, ‘M26’ and ‘MM106’ 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 for 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 woolly apple aphid (WAA) infestation.

Hardwood cuttings (ideally ~ 30 cm in length) are taken of these selections at the beginning of December and are dipped in 0.5% (Indole-3-butryic acid) IBA 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 25^{o}C. 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 cultivar (currently ‘Gala’ for apples and ‘Conference’ for pears) and established in replicated trials that include standards commercial rootstocks for control purposes.

In these trials tree vigour is assessed by the measurement of tree volume (either in the form of the number and length of shoots for trees < 3 years old, or by the measurement of 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.

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

Summary of the project and progress made

1. New seedling populations

1.1. Apple

Seeds from the 2011 crosses were extracted (Table 1) but due to poor fruit set, it was decided to complement them with additional seeds from previous crosses stored for this eventuality. Families where a second lot of seed was being sown were differentiated from the previous population by adding ‘a’ to the family code, for example, 140 individual of the ‘Geneva 30’ open pollinated (o.p). seed lot were planted in 2010 as family M555 whilst, from the same seed lot, 129 seedlings were raised in 2012 as family M555a. In total, 35 trays of seeds were sown, including 15 (761 seed) of the M27 x Geneva 30 crossed that failed to produce viable seedlings in 2011. Seed trays went into cold storage in the third week of December and given 12 weeks of chilling at 2°C approximately. In March 2011 they were transferred to a heated glasshouse under natural lighting to germinate. In general, emergence was good, with the expected exception of M561, of which only six seedlings could be potted up. Germination rate in M564 was also below 50% (Table 1). In total 807 seedlings were raised and grown on for planting in the summer of 2011.

Table 1. Apple rootstock seedling germination in 2012

Family	**Cross**	**Year of crossing**	**Seeds**		**Germination**	**Potted**
			Sown	Trays		

M555a	Geneva 30 o.p.	2009	**150**	3	86%	129
M556a	Ottawa 3 o.p.	2009	**100**	2	91%	91
M559a	Bud.9 x M.9	2010	**74**	2	80%	59
M560a	AR86-1-20 x Geneva 11	2010	**200**	4	95%	189
M561	M27 x Geneva 30	2010	**761**	15	1%	6
M562a	MM106 x Geneva 202	2010	**231**	5	95%	220
M563a	MM106 x Bud. 9	2010	**99**	2	93%	92
M564	Geneva 202 x M27	2011	**35**	1	31%	11
M565	Bud.9 x M116	2011	**10**	1	100%	10

A total of 914 new apple seedlings from six different progenies, all originated from controlled crossing, were planted at in August 2011 (Table 2). The plot (SC199) was laid out in parallel rows to the previous year planting (SC198) to form an alternated double row with a 50 cm spacing between trees in the row, 1 m spacing within the double row and 3.5 m alleys.

Table 2. New apple rootstock progenies planted in 2011 (SC199)

Progeny number	♀		♂		Seedlings planted
	Rootstock	Characteristics[1]	Rootstock	Characteristics[1]	
M557	M116	semi-vigorous, res to crown & collar rots, waa res, FB sus, low suckering	M9	dwarfing, waa sus, FB sus	93
M558	Geneva 30	semi-dwarfing; FB res; collar rot resistant; early bearing; productive	M116	semi-vig, res to crown & collar rots, waa res, FB sus, low suckering	114
M559	Bud 9	dwarfing, precocious, winder hardy, mod res FB, collar rot res	M9	dwarfing, waa sus, FB sus	110
M560	AR86-1-20	semi-vig, waa res, good yield efficiency	Geneva 11	dwarfing , precocious, gd rooting, fairly FB and waa res	242
M561	M27	very dwarfing, waa sus, FB sus	Geneva 30	semi-dwarfing; FB res; collar rot resistant; early bearing; productive	0
M562	MM106	semi-vigorous, precocious, heavy cropping, waa res, good wue	Geneva 202	moderate dwarfing; waa res, FB res, high yield efficiency	228
M563	MM106	semi-vigorous, precocious, heavy cropping, waa res, good wue	Bud 9	dwarfing, precocious, winder hardy, mod res FB, collar rot res	127

[1] where waa = woolly apple aphid, FB = fire blight, wue = water use efficiency, sus = susceptible, res = resistant

1.2. Pear

No new pear progenies were raised in spring 2012 but seed from the two crosses (Table 3) was extracted and stored for germination in 2012. However, during the previous August, 690 new seedlings from six different progenies (Table 4) were planted. The plot (SC200) was laid out as alternating double rows with trees spaced 50 cm in the row, 1.5m within the double row and 3.5 m alleys.

Table 3. Pear rootstock seeds produced in 2011 currently in storage.

Family	Cross	Objective	Seeds
PRP51	OHxF87 x P525-3	Dwarfing & scion compatibility	9
PRP52	BP1 x P525-3		442

Table 4. New pear rootstock progenies planted in 2011 (SC200)

Progeny number	♀		♂		Seedlings planted
	Rootstock	Characteristics[1]	Rootstock	Characteristics[1]	
PRP45	PB 11-30	Very early, precocious, heavy cropper	OHxF 87	Semi-dwarfing, precocious, slightly more dwarf than OHxF 97	93
PRP46	B14	Selected in South Africa; heat tolerant	o. p.		114
PRP47	BP1	Selected in South Africa; dwarfing, heat tolerant, not very easy to root	*P. betulifolia*	Very vigorous, excellent rooting, winter hardy, FB res, tolerant to pear decline	110
PRP48	OHxF 333	More invigorating than BA29, resistant to FB and pear decline	Junsko Zlato	Good precocity	242
PRP49	PB11-30	Very early, precocious heavy cropper	OHxF 333	More invigorating than BA29, resistant to FB and pear decline	0
PRP50	OHxF 87	Semi-dwarfing, precocious, slightly more dwarf than OHxF 97	BP1	Selected in South Africa; dwarfing, heat tolerant, not very easy to root	228

[1] where FB = fire blight, sus = susceptible, res = resistant

2. Seedling populations in the pipeline

2.1. Apple

More than 1,000 seedlings from families M553 (AR86-1-20 x G.202), M554 (MM106 x G.30), M555 (G.30 o.p.) and M556 (Ottawa 3 o.p.) planted in 2010 as well as controls ranging in vigour (M27, M9, M26 and MM106) planted in January 2011 as one-year-old commercially-purchased rootstocks, were budded in August with the columnar scion SA544-28 (plot SC198).

Vigour, crop and presence of suckers was recorded on seedlings in plot SC184 (family M508, budded in 2007) and SC190 (AR, M580, M545, M546, M547, M548, M549). No records will be taken of families in SC194 until 2012.

2.2. Pear

A total of 364 seedlings from families PQ40 and PQ41 (SC185, planted in 2005) and PQ42, PQ43 and PQ44 (SC193, planted in 2006) were evaluated in September 2011. Records were taken of their vigour, incidence of suckering and, if appropriate, crop load.

3. Selection

3.1. Apple

After three years of evaluation in SC183, 17 apple selections were made from the progenies planted in 2005. No selections were made from the M480 (M9 x M116) family but no conclusions can be drawn on the potential value of the cross as only 17 seedlings were available. In families M481 (M9 x G.202) and M482 (M9 x M116/G.202), 2 and 15 selections were made respectively (Table 5).

3.2. Pear

No new selections were made in 2011, but notes observations were made on the selections made in previous years regarding vigour, health and number of shoots produced.

4. Propagation

4.1. Selections being bulked up for trialling

Seedlings selected in 2011 (Table 5) were cut back and covered with compost in February 2012 to encourage the production of shoots. Efforts to propagate selections made in previous years continued; shoots were collected in early January and placed in heated bins for rooting (Table 6). In general, shoot production and quality was disappointing in the apples and more satisfactory in the pear selections.

Table 5. Characterisation of apple rootstock selections made in 2011

Selection number	Vigour[1]			Crop load[2]			Suckering[3]		
	2009	*2010*	*2011*	*2009*	*2010*	*2011*	*2009*	*2010*	*2011*
M481-5	mv	mv	m	h	-	vh	++	+	+
M481-10	mw	w	w	h	-	m	++	++	+
M482-11	m	m	m	ml	vl	mh	-	-	-
M482-13	w	w	w	vl	-	mh	++	+++	+
M482-42	m	m/mw	mw	ml	-	h	+	-	+
M482-44	m	mw	m	h	-	h	++	++	+
M482-49	m	m	mv	m	-	h	++	++	-
M482-54	mv	m	m	mh	l	h	++	+	+
M482-65	m	m	m	l	h	h	-	-	+
M482-76	m	m/mv	m	ml	h	vh	++	+	+
M482-84	m	m	m	h	mh	h	++	+	+
M482-87	m	mw	mw	h	h	m	+	+	+
M482-110	m	m	m	h	-	h	+	+	-
M482-133	m	m	m	h	mh	mh	-	+	+
M482-153	m	mw	mw	h	mh	h	++	+	+
M482-158	mv	m/mv	mv	h	l	h	++	++	+
M482-175	mv	m	m	m	h	h	++	++	+

[1]where w = weak, mw = medium-weak, m = medium, mv = medium-vigorous and v= vigorous
[2]where vl = very light, l= light, ml = medium-light, m= medium, mh = medium-heavy, h = heavy and vh = very heavy
[3]where – = absent , + = a few present, ++ = several present and +++ = many present

Table 6. Apple and pear rootstock selections undergoing propagation

Selection Number	Crop	Shoots collected	Comments
M345-3	Apple	0	
M345-18	Apple	5	Generally small shoots
M345-32	Apple	6	
M360-9	Apple	6	
M360-21	Apple	3	
M360-63	Apple	4	
M360-64	Apple	6	
M360-84	Apple	8	Generally weak shoots; some evidence of herbicide damage
M360-115	Apple	0	
M360-149	Apple	3	
M360-163	Apple	0	
M360-172	Apple	1	
M360-191	Apple	3	
M432-203	Apple	8	OK
M432-217	Apple	5	OK
M432-243	Apple	5	OK
M432-247	Apple	6	OK
M432-250	Apple	> 10	OK, many shoots
M430-217	Apple	5	OK
M430-249	Apple	7	OK
PQ37-1	Pear	6	OK
PQ37-2	Pear	> 10	OK
PQ37-3	Pear	> 10	OK
PQ37-4	Pear	5	OK
PQ37-5	Pear	> 10	OK
PQ37-6	Pear	2	OK
PQ37-7	Pear	8	OK
PQ37-8	Pear	> 10	OK
PQ38-1	Pear	5	OK
PQ38-2	Pear	6	OK
PQ39-1	Pear	> 10	OK
PQ39-2	Pear	> 10	OK
PQ39-3	Pear	> 10	OK
PQ39-4	Pear	8	OK
PQ39-5	Pear	5	OK
PQ39-6	Pear	10	Small shoots
PQ39-7	Pear	> 10	OK
PQ39-8	Pear	> 10	OK

4.2. Screening advanced selections for pest and disease

Propagation material was taken from advanced selections currently undergoing HDC-funded trials (Table 7) in order to determine their response to woolly apple aphid (WAA) and fire blight (FB). Hard wood cuttings were placed in heated bins for rooting at EMR for subsequent inoculation with WAA colonies collected in the field. Whereas, grafting sticks were sent to Dr Klaus Richter (Julius Kuehn-Institute, Germany) through 'Lubera' for FB inoculation.

Table 7. Propagation material collected from advanced selections for pest and disease screening; expected response in indicated where known

Selection number	Parentage		Trial plot	Woolly apple aphid		Fire Blight	
	♀	♂		**Response**	**HWC[1]**	**Response**	**Grafts[2]**
AR295-6	Robusta 5	Ottawa 3		Sus	10	Sus?	-[3]
B24	AR10-2-5	AR86-1-22	EE207	?	10	?	10
R59	AR134-31	AR86-1-22	EE207	?	10	?	10
R80	AR134-31	AR86-1-22	VF224	?	10	?	10
R104	AR134-31	AR86-1-22	EE207	?	10	?	10
AR10-3-9	MM106	M27	VF224	?	10	Sus[4]	10
AR809-3	R80	M26	VF224	?	10	?	10
AR835-11	MI793	M9A	VF224	?	10	?	10
AR839-9	M7	M27	EE207	Sus[4]	10	?	10
AR852-3	AR362-16	op	EE207	Sus?	10	?	10

[1]Hard wood cutting placed in heated bins for rooting at EMR
[2]Sticks for grafting sent to Dr Klaus Richter (Julius Kuehn-Institute, Germany) through 'Lubera' for FB testing
[3]Currently being re-tested for FB susceptibility in Switzerland through Pepival
[4]Both parents are known to be susceptible
[5]Mother known to be susceptible, parent pollen unknown

5. Preliminary trials

5.1. Apple

A new apple rootstock trial, with 'Gala' as a common scion, was planted in March 2012 according to a randomised design (Fig. 1) including M9, M116 and MM106 as controls. All the selections in this trial are derived from a cross between EMR selection 'AR86-1-20' and 'M20' and it seems that they range considerably in vigour. Trees were planted in two rows (5 m × 3 m) with guards on M9 at the ends and between blocks; the guards will also act as pollinators, having been worked with 'Fiesta' and 'Braeburn'.

DNA testing was carried out to ensure that all selections and controls were true to type (Table 8). DNA was extracted from young roots taken of all the trees available for the trial and compared to that of the original seedling using SSR markers. Trees for which some markers failed to amplify or showed any anomalies (shaded in the table) were not used in the trial as a precaution. Scions and guards were not fingerprinted at this stage.

R1	T1	g/p	Braeburn*	R2	T1	g/p	Fiesta*
R1	T2	1	M306-79	R2	T2	3	M306-20
R1	T3	1	**M116**	R2	T3	3	**MM106**
R1	T4	1	**M9**	R2	T4	3	M306-79
R1	T5	1	M306-6	R2	T5	3	M306-6
R1	T6	1	M306-189	R2	T6	3	**M116**
R1	T7	1	M306-20	R2	T7	3	**M9**
R1	T8	1	**MM106**	R2	T8	3	M306-189
R1	T9	g/p	Fiesta*	R2	T9	g/p	Braeburn*
R1	T10	2	**MM106**	R2	T10	4	M306-6
R1	T11	2	M306-79	R2	T11	4	M306-189
R1	T12	2	M306-189	R2	T12	4	M306-79
R1	T13	2	M306-6	R2	T13	4	**M9**
R1	T14	2	**M9**	R2	T14	4	M306-20
R1	T15	2	**M116**	R2	T15	4	**M116**
R1	T16	2	M306-20	R2	T16	4	**MM106**
R1	T17	g/p	Braeburn*	R2	T17	g/p	Fiesta*

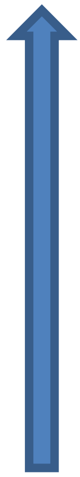

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Figure 1. Plot plan for new apple rootstock preliminary trial (RF185).

Table 8 . Genotypes of the EMR apple rootstock selections and vigour controls for the new apple rootstock trial as revealed by 12 SSR markers. Reference samples are indicated as _TTT (True-to-type) after the name.

	CH04c07			CH01h10		CH01h01		Hi02c07		CH01f02		CH01f03b		GD12		GD147		CH02c11		CH02c09		CH02d08		CH04e05	
1_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
2_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
3_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
4_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
5_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
6_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
7_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
8_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
9_M360-6	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
M306_006_TTT	110	120		96	113	111	119	114	116	168		170	178	148	182	139		215	229	232	244	210		220	222
10_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
11_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
12_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
13_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
14_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
15_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
16_M9	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
25_83_M9_TTT	106	114	129	96	113	113	119	116		168	170	158	170	148	160	139	152	213	233	244		212	254	196	220
17_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
18_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
19_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
20_MM106	-	-	-	-	-	-	-	-	-	172	180	136	170	148		139	143	205	229	244	254	210	228	173	
21_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
22_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
23_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
24_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
25_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
26_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
EM_B_14_MM106_TTT	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
MM106_Gbank	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
25_87_MM106	110	114	129	96		129		116		172	180	136	170	148		139	143	205	229	244	254	210	228	173	
27_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
28_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
29_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
30_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
31_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
32_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
33_M306-20	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
M306_020_TTT	110			96	100	111	129	114	116	168	180	136	158	148		139		225	229	232	244	210	216	173	222
34_M306-79	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
35_M306-79	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
36_M306-79	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
37_M306-79	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
38_M306-79	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
M306_079_TTT	110	120		96	113	111	119	114	116	168		158	170	148		139		225	229	232	244	210		173	220
39_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		-	-	-	-	-	-	-	-
40_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
41_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
42_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
43_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
44_M306-189	96	110		96	113	111	129	116		168		158	172	148	182	139		-	-	-	-	-	-	-	-
45_M306-189	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
M306_189_TTT	96	110		96	113	111	129	116		168		158	170	148	182	139		215	217	232	250	210	216	173	222
46_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
47_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
48_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
49_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
50_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
51_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
52_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
53_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
54_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
55_M116	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208
M116_Pot_TTT	110	114	129	96	113	129		114	116	168	180	136	170	148		139	143	217	229	244	254	210	212	173	208

5.2. Pear

Two trials of rootstocks for pear were evaluated in 2011; DM177 and DF178 (both planted in 2006), including quince rootstocks EMA and EMC as controls. As in previous years, it was difficult to see differences between the controls (all EMA were obtained from 'Blackmoor' nursery, EMC standards were source from 'Blackmoor' and 'Keepers' nurseries). It was expected that the EMC rootstocks obtained from two different nurseries would perform similarly. However, trees on EMC rootstocks from 'Keepers' nursery continue to appear intermediate between those on EMA and EMC from 'Blackmoor' and therefore samples have been taken for DNA analysis. Tables 9 and 10 summarise the results for DM177 (*Pyrus*) and DM178 (quince) respectively. Although both tables show a number of differences, not all of them are statistically significant. Moreover, due to the very small number of trees evaluated for some of the selections, results should be interpreted cautiously. Statically significant differences between the selections and the different controls have been compiled in Table 11 and 12 to facilitate interpretation.

In the *Pyrus* plot (DM177), PQ34-3 ((*P. communis* Ankara op) x (B13 x Old Home)) with a vigour similar to that of QA, continued to produce the largest yields but with a majority of the fruit being smaller than 65 mm. PQ35-1 and PQ35-3 ((B13 x Old Home) x (B13 x Old Home)) appear to be the most dwarfing rootstocks in the trial, with a yield of fruit > 65 mm and yield efficiency not significantly different from those of the controls. However, the results for the latter selection should be considered prudently as there is only one tree available in the trial.

Even fewer significant differences can be picked up in DM178 where, being the quince trial, the requirements would be more stringent. On average, PQ5-3 and PQ5-13 show the highest yield efficiency, with trees smaller than the controls. However, due to the differences in replication level these are not statistically significant.

Table 9. The effects of EMR *Pyrus* rootstocks on the growth and cropping of 'Conference' pear trees in 2011 compared with quince standards (QA and QC). DM177 plot planted in March 2006.

Rootstock	Trees planted (alive)	2011 data					Cumulative data (2007-2011)		
		Girth (cm)	Tree Volume (m^3)	Total Yield (kg)	Class 1 fruit (kg/tree)		Total Yield (kg/tree)	Class 1 fruit >65mm (kg/tree)	Yield efficiency (kg/cm^2)
					> 65mm	55-65mm			
PQ34-1	2 (2)	13.6	3.5	11.7	2.2	2.9	18.3	4.8	1.25
PQ34-2	6 (6)	10.3	2.5	4.1	0.4	0.8	6.3	0.6	0.67
PQ34-3	4 (4)	15.8	5.2	15.2	1.3	4.3	25.3	3.6	1.30
PQ34-4	2 (2)	9.8	2.2	2.1	0.0	0.1	3.0	0.0	0.39
PQ34-5	2 (2)	12.5	2.7	8.4	0.2	1.1	11.2	0.4	0.88
PQ34-6	1 (1)	14.6	3.6	10.1	0.4	0.9	21.7	2.0	1.28
PQ35-1	5 (5)	9.6	1.5	1.0	0.0	0.0	3.6	0.3	0.48
PQ35-2	1 (1)	12.3	2.0	2.7	0.0	0.3	14.7	1.6	1.22
PQ35-3	1 (1)	4.1	0.1	0.3	0.0	0.0	1.2	0.4	0.90
EMA	15 (15)	15.5	4.4	11.8	1.3	3.1	18.9	3.7	1.01
EMC_B[1]	6 (6)	11.1	1.9	4.5	0.0	0.3	9.3	1.2	0.91
EMC_K[2]	5 (5)	14.2	3.0	9.7	0.2	0.4	17.4	1.8	1.10
SED (38 d.f.)		1.74	1.23	2.42	1.22	1.18	4.00	1.75	0.311
Significance[3]		***	***	***	ns	***	***	**	**
LSD p=0.05		3.51	2.49	4.90	2.47	2.38	8.10	3.55	0.629

[1]ex Blackmoor
[2] ex Keepers
[3] *, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect

Table 10. The effects of EMR quince rootstocks on the growth and cropping of 'Conference' pear trees in 2011 compared with standards (QA and QC). DM178 plot planted in March 2006.

Rootstock	Trees planted (alive)	2011 data					Cumulative data (2007-2011)		
		Girth (cm)	Tree Volume (m^3)	Total Yield (kg)	Class 1 fruit (kg/tree)		Total Yield (kg/tree)	Class 1 fruit >65mm (kg/tree)	Yield efficiency (kg/cm^2)
					> 65mm	55-65mm			
PQ5-1	3 (3)	13.3	3.2	8.5	0.4	1.6	15.2	2.1	1.09
PQ5-2	4 (4)	15.1	3.5	11.9	0.7	2.5	22.4	2.3	1.19
PQ5-3	3 (3)	11.9	2.8	9.3	1.1	2.3	17.9	2.4	1.68
PQ5-6	3 (3)	16.8	6.0	14.7	0.2	3.6	27.0	2.2	1.20
PQ5-7	1 (1)	12.2	3.8	2.5	0.0	0.2	8.6	1.4	0.73
PQ5-8	1 (1)	14.8	4.1	9.2	0.1	2.1	21.9	3.4	1.26
PQ5-9	5 (5)	13.7	3.3	9.2	0.3	2.0	12.5	1.4	0.82
PQ5-10	3 (3)	13.5	3.2	8.2	0.6	1.9	10.9	1.7	0.74
PQ5-11	2 (2)	11.4	1.7	5.5	0.5	0.9	7.4	0.5	0.72
PQ5-12	2 (2)	10.7	2.0	5.8	0.8	1.5	10.7	2.2	1.16
PQ5-13	2 (2)	11.7	2.6	8.6	0.5	2.7	17.9	2.3	1.66
PQ5-16	4 (4)	16.6	6.4	13.6	1.2	4.7	24.6	4.0	1.12
PQ5-18	4 (3)	15.7	4.6	13.4	2.2	4.4	23.7	5.2	1.27
PQ5-19	2 (2)	10.7	1.9	5.9	0.0	0.7	11.0	1.0	1.18
PQ5-20	2 (2)	14.5	2.8	12.9	0.4	3.3	20.6	2.8	1.20
PQ5-21	1 (1)	12.9	2.0	8.6	0.1	1.1	15.4	0.4	1.16
PQ5-22	2 (2)	17.5	4.8	14.4	3.5	4.8	25.8	7.1	1.06
EMA	15 (14)	15.9	5.0	13.5	2.9	3.5	23.9	5.9	1.19
EMC_B[1]	6 (6)	12.5	3.9	9.0	0.5	1.8	17.7	3.5	1.38
EMC_K[2]	5 (5)	14.2	2.7	7.6	0.0	1.0	18.7	3.4	1.13
SED (48 d.f.)		2.02	1.40	3.56	1.34	1.67	6.14	2.12	0.281
Significance[3]		***	***	**	**	*	***	***	**
LSD p=0.05		4.05	2.81	7.15	2.70	3.35	12.35	4.26	0.565

[1]ex Blackmoor
[2] ex Keepers
[3] *, ** and *** indicates rootstock effect significant at the 5, 1 and 0.1% level respectively, ns indicates no significant effect

Table 11. Summary of the interpretation of *Genstat* results for Pyrus rootstock trial in DM177. Statistically significant differences (at 5% level) between the selection and the controls are indicated: 'L' denotes a value lower than the control and 'H' a value higher than the control.

Pyrus	Planted	Girth			Tree Volume			Total Yield 11			>65mm Yield 11			55-65mm Yield			C. Yield			C. Yield >65mm			Yield Efficiency		
Rootstock	(alive)	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B
PQ 34-1	2 (2)	*	*	*	*	*	*	*	*	H	*	*	*	*	H	H	*	*	H	*	*	*	*	*	*
PQ 34-2	6 (6)	L	L	*	*	*	*	L	L	*	*	*	*	*	*	*	L	L	*	*	*	*	*	*	*
PQ 34-3	4 (4)	*	*	H	*	*	H	*	H	H	*	*	*	*	H	H	*	*	H	*	*	*	*	*	*
PQ 34-4	2 (2)	L	L	*	*	*	*	L	L	*	*	*	*	L	*	*	L	L	*	L	*	*	*	L	*
PQ 34-5	2 (2)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ 34-6	1 (1)	*	*	*	*	*	*	*	*	H	*	*	*	*	*	*	*	*	H	*	*	*	*	*	*
PQ 35-1	5 (5)	L	L	*	L	*	*	L	L	*	*	*	*	L	*	*	L	L	*	*	*	*	*	*	*
PQ 35-2	1 (1)	*	*	*	*	*	*	*	L	*	*	*	*	L	*	*	*	*	*	*	*	*	*	*	*
PQ 35-3	1 (1)	L	L	L	L	L	*	L	L	*	*	*	*	L	*	*	L	L	*	*	*	*	*	*	*
EMA	15 (15)	n/a	*	H	n/a	*	*	n/a	*	H	n/a	*	*	n/a	H	H	n/a	*	H	n/a	*	*	n/a	*	*
EMC_B	6 (6)	L	*	n/a	*	*	n/a	L	L	n/a	*	*	n/a	L	*	n/a	L	L	n/a	*	*	n/a	*	*	n/a
EMC_K	5 (5)	*	n/a	*	*	n/a	*	*	n/a	H	*	n/a	*	L	n/a	*	*	n/a	H	*	n/a	*	*	n/a	*

Table 12. Summary of the interpretation of *Genstat* results for Pyrus rootstock trial in DM178. Statistically significant differences (at 5% level) between the selection and the controls are indicated: 'L' denotes a value lower than the control and 'H' a value higher than the control.

Pyrus	Planted	Girth			Tree Volume			Total Yield 2011			>65mm Yield 2011			55-65mm Yield '11			C. Yield			C. Yield			Yield Efficiency		
Rootstock	(alive)	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B	QA	QC_K	QC_B
PQ5-1	3 (3)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-2	4 (4)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-3	3 (3)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-6	3 (3)	*	*	H	*	H	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-7	1 (1)	*	*	*	*	*	*	L	*	*	L	*	*	*	*	*	L	*	*	L	*	*	*	*	L
PQ5-8	1 (1)	*	*	*	*	*	*	*	*	*	L	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-9	5 (5)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	L	*	*	*	*	L
PQ5-10	3 (3)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	L	*	*	*	*	*	*	*	L
PQ5-11	2 (2)	L	*	*	L	*	*	L	*	*	*	*	*	*	*	*	L	*	*	L	*	*	*	*	L
PQ5-12	2 (2)	L	*	*	L	*	*	L	*	*	*	*	*	*	*	*	L	*	*	*	*	*	*	*	*
PQ5-13	2 (2)	L	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-16	4 (4)	*	*	H	*	H	*	*	*	*	*	*	*	*	H	*	*	*	*	*	*	*	*	*	*
PQ5-18	4 (3)	*	*	*	*	*	*	*	*	*	*	*	*	*	H	*	*	*	*	*	*	*	*	*	*
PQ5-19	2 (2)	L	*	*	L	*	*	L	*	*	L	*	*	*	*	*	L	*	*	L	*	*	*	*	*
PQ5-20	2 (2)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PQ5-21	1 (1)	*	*	*	L	*	*	*	*	*	L	*	*	*	*	*	*	*	*	L	*	*	*	*	*
PQ5-22	2 (2)	*	*	H	*	*	*	*	*	*	*	H	H	*	H	*	*	*	*	*	*	*	*	*	*
EMA	15 (15)	n/a	*	*	n/a	*	*	n/a	*	*	n/a	H	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*
EMC_B	6 (6)	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a
EMC_K	5 (5)	*	n/a	*	*	n/a	*	*	n/a	*	L	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*	*	n/a	*

7. Distribution of propagation material from advanced selections

Leaf samples from R104 and R59 stocks maintained at I.F.O. were sent to EMR for DNA verification in August 2011. Tests carried out in February 2012 comparing these samples to those taken from EMR mother trees, revealed that both samples were in fact R104 (Table 13). Thus graft wood of true-to-type R59 will be supplied in 2012-13.

AR809-3 did not produce many shoots in 2011 thus no material could be sent to IFO in the reporting year but we will aim to supply it in 2012-13.

Table 13. Genotypes of the EMR apple rootstock selections maintained at IFO as revealed by 12 SSR markers. Reference samples kept at EMR are indicated as _TTT (True-to-type) after the name.

Sample	CH04c07			CH01h01		CH01h10		Hi02c07		CH01f02		CH01f03b		GD12		GD147		CH02c09		CH02c11		CH02d08		CH04e05	
M.9	106	114	129	113	119	96	113	116	0	168	170	158	170	148	160	139	152	244	0	213	233	212	254	196	220
R104 (ex IFO)		114	129	97	129	96	113	114	116	168	172		170	148		131	139	243	254	205	229		228	173	208
R104_TTT		114	129	97	129	96	113	114	116	168	172		170	148		131	139	243	254	205	229		228	173	208
R59 (ex IFO)		114	129	97	129	96	113	114	116	168	172		170	148		131	139	243	254	205	229		228	173	208
R59_TTT	108	114	129	97	129	86	96	114	118	172	178	136	170	148		131	139	243	254	205	232	210	228	173	208

1.8. Germplasm introduction and characterisation

The process of introduction new apple genotypes from the Cornell Geneva(R) programme namely 'G.41', ‘G.16’ and ‘G.935’ has been thus far unsuccessful. On the other hand, plants of Pyro^{TM}Dwarf are establishing well and will be used for crossing as soon as they flower. Plants and pollen of the ornamental apple ‘Evereste’ have also been introduced to be used in the 2012 crossing programme as a source of fire blight resistance.

As part of the efforts to rationalise the EMRBC germplasm collection, planning the re-propagation of apple genebank has been started. To facilitate future verification, DNA samples have been taken of a first batch of 104 genotypes. Characterisation using 12 SSR markers is presented in Table 14.

1.9. EMRC web page

The EMRC internet site (www.emrootstockclub.com) ‘hangs’ from EMR’s main page and contains a restricted area for club members where contracts, reports and other relevant information is regularly up-dated. Those eligible to access the members-only area, should contact Feli Fernández (felicidad.fernandez@emr.ac.uk) to apply for a user name and password.

Table 14. Genotypes of the EMR apple rootstock selections maintained at IFO as revealed by 12 SSR markers.

	CH04c07	CH01h10	CH01h01	Hi02c07	CH01f02	CH01f03b	GD12	GD147	CH02c11	CH02c09	CH02d08	CH04e05
EM_B_19 _MM111	106 110	88 101	103 117	114 116	182 186	170 178	147	137 145	194 205	232 244	210	173 220
EM_B_21_MM112	106 133	88 96	103 119	110 116	178 182	170 178	148	131 137	194 205 218	232 244	248 254	173 208
EM_B_23_MM113	106	88 96	103 115	116 118	170 184	136 178	147	137 143	194 205 231	244 256	228 248	208 218
EM_B_25_MM115b	106 120	96	103 129	116	168 180	170 182	148 153	137 139	205 226	232	210 248	173 220
EM_B_43_Northern Spy	106 110	88 96	103 129	116	182	170 178	147	137 143	194 205	232 244	210 248	173 208
EM_B_45_Crab 'C'	106	96	119 125	114 116	178 193	158 162	151	135 139	205 233	232 256	210 254	200 218
EM_B_47_M. robusta 5a	106 108	86 109	86 95	116 118	174 178	170	151	145 150	204 218	247	210 212	181
EM_B_49_M. praecox	106 110	96 101	109 117	114	186 203	158 170	148 151	137 143	194 214	232 254	210 216	196 220
EM_B_51_Alnarp 2	96 110	96 100	115 127	116 150	168 203	158 170	148 182	150 152	194 216	244 254	246 254	173 196
EM_C_20_Nesravennoe	94 96	96 100	113 117	116 124	178 182	143 158	154	137	218 224	232 256	222	173 200
EM_D_11_Ottawa 3	108 114 129	86 96	113 119	110 116	170 178	158	148 182	139 150	194 214	244 248	214 254	181 196
EM_D_13_Polish 22	106 135	113 115	113	116 118	168 170	136 170	148 160	150 152	222 233	244 248	212 246	200 226
EM_D_16_Budagovsky 9	96 104	96 103	121 129	116 148	168 182	158 170	182	139 143	194 214 229	232 248	210	200 220
EM_I_10_Ottawa 521	96 112	96 100	113 119	114 124	172 205	170	150 182	131 150	194 229 233	232 256	210 254	173 222
EM_01_12_Mac 4	110 112	96	117 129	116 150	186 203	136 158	148 153	137 150	216 226	232	250 254	173
EM_01_13_Mac 9	108 114 129	96 109	113	116	170 186	168 170	148 160	131 139	214 233	244 254	212 216	189 220
EM_01_14_Mac 24	106 108	86 96	86 113	106 116	168 174	158 170	148 150	131 145	204	247 254	210 212	181 189
EM_04_03_M. floribunda	108	101 109	103 137	114 135	174 178	148	148 172	123	222 226	230 250	214 218	187 196
EM_04_05_M. hupehensis	110 114	93 96 103 111	101 117 129	114 120 130 131	182 184 186 195	148 170	148 151 170	125 127 150	200 204 212 222	232 238	208 210 216 221	173 177 189 198
EM_04_07_M. platycarpa	94 102 126 128	82 86 96	99 111 115	108 116 124	178 186 188 205	172	148 153 166 180	127 131 139	205 212 214	241 243 254 258	200 226	200
EM_04_09_M. robusta	108 110	96 109	86 115	108 114	186 217	148 158	148 151	137 152	204 214	245 254	210 216	189 208
EM_04_11_M. robusta erecta	96 108	107 109	86 109	118 122	168	148 170	158 164	137	229	250	210 212	181 196
EM_05_04_Wijcik	104 106	88 96	113 115	110 118	172 203	158 170	148 182	131 137	226 229	232 256	210 228	200 208
EM_08_20_Ohio no 3	106 120	96	117 119	116	172 178	170 178	148 160	131 137	205 235	232 242	210 228	196 208
EM_09_07_M. pumila Aurea	108 110	96 131	111 113	110 114	170 201	143 170	151 154	131 147	214 235	238	252 254	173 222
EM_10_01_M. baccata	112	115 117	101 115	114	168 188	146	151	119 125	205	238	210 214	187
EM_10_03_M. baccata flexilis	106 108	101 109	86 113	114 118	178 182	148 158	151 166	131 145	204 222	248 250	212 224	189 222
EM_10_05_M. baccata gracilis	108 120	100 107	121 129	114	182 186	170	148 151	137 150	204 216	232 252	216 254	173 222
EM_10_15_M. brevipes	108	101 103	117 137	114	176	146 148	147 151	123 135	216 239	244 254	218 246	187 208
EM_10_17_M. denticulata	106 108	96 109	113 115	108 116 124	186 203	170 178	147	131 137	214 216	232 245	210 212	196 222
EM_10_18_M. robusta persicif	96 108	107 109	109 115	116 118	174	148 170	151 158	131 137	204 229	250	212	181 202
EM_10_19_M. florentina	110 143	107 113 115	107 137	108 128	150 152	182	151 161	133 139	212	226	198	175 190
EM_10_21_M. floribunda J	108	101 109	103 137	114 135	174 178	148	148 172	123	222 224	230 250	214 218	187 196
EM_10_22_M. floribunda	108	101 109	103 137	114 135	174 178	148	148 172	123	222 226	230 250	214 218	187 196
EM_10_23_M. fusca	108	101 109	103 137	114 135	174 178	148	148 172	123	222 226	230 250	214 218	187 196
EM_11_01_M. halliana	104 116 130	84 109 115	123 125	112 126 128	180 188 201	148	132 153 156	123	202 231	244 251	218 226 230	187 189 200
EM_11_02_M. tschonoskii	110	121 125 135	95	112 120	182 195	218 226	147 160	137	202	226	218	183 196
EM_11_14_M. zumi	108	101 111	99 103	135 142	174 176	148	147 162	123 150	200 222	252 254	214 218	192 222
EM_11_16_M. zumi calocarpa	- -	101 109	86 105	114 137	174 217	148	147 157	123	202 222	226 250	214 222	181 192
EM_14_05_9AR2T17	108 133	88 96	115	116 135	178 205	143 178	148 153	137 147	205 222	238 254	210 254	173
EM_14_07_OR51T86	104 108	96 109	111 119	118 150	203 205	148 170	148	123 131	224 233	242 248	252 254	173 200
EM_14_15_PI286613=Novole	- -	94 105	107 115	130 133	176 180	148	147 152	125 127	200	246	210 212	190 200
EM_14_17_R. Seedling 12740-7A	106 110	96 101	109 117	114	186 203	158 170	148 151	137 143	214	232 254	210 216	196 220
EM_16_01_M. arnoldiana	108 133	101 107	107 119	118 135	174 205	148 162	148	150	229 235	254 256	210 218	173 196
EM_16_05_M. baccata illipsoides	114 118 126	90 105 111	109 123	114 131	164 195	148	151 157	119 121 123	200 210 212	239	210 224 232	177 190
EM_16_07_M. baccata jackii	108	86 105	113	118	176 235	148	151	131 149	204	244	214 218	181 208
EM_16_09_M. baccata mandsh.	108 116 135	98 101 115	86 101 117	116 128 130 135	176 193 233	148	148 153 160 164	119 123	200 204 208 224	226 256 266	212 214 233	181 190 196
EM_16_12_M. brevipes	108	86 109	103 117	130	174 176	148	147	125 149	216 222	230 244	212 246	192 200
EM_16_16_M. florentina	110 143	107	107 137	108 128	150 152	182	152 161	139 141	212	226	198 212 224	175 190
EM_16_18_M. glaucescens	106	101	127 137	114 118	174 176	148	166 172	123 149	204 224	230 252	214 224	187 222
EM_16_20_M. hartwigii	108 130	98 115	113 121	114 118	160 178	170 180	151 157	123 145	237 239	250 252	212 222	189 192
EM_16_23_M. hupehensis	114	93 103 111	101 117	120 130 131	182 184 195	148	151 170	121 123	200 204 212	238	208 216 221	177 189 198
EM_16_26_M. koreana	108 110	100 105	113 117	118	168 186	146 170	150 157	137 145	214 235	242	218 246	181 208
EM_16_28_M. lemoinei	110 126	101 103	103 115	114 135	160 174	148 156	156	123	222 239	244 250	212	196 231
EM_16_30_M. orthocarpa	110 120	101 131	111 135	110 135	188 199	170	151 156	131 147	231 235	238 250	210 254	196 222
EM_16_34_M. platycarpa	104 118	82 88	95 115	108 114 118 126	170 172 198	170 172	148 151 161	133 137 139	210 216 229	248 254	198 200 212 228	196
EM_16_36_M. prattii	120 122	109	97 121	108 135	168 188	206 208	- -	123 135	204	220 248	206	187 198
EM_17_01_M. robusta	106 108	86 109	86 97	116 118	174 178	170	150 151	145 150	204 218	247	210 212	181
EM_17_02_M. sargentii	116	101 115	101 107 115	114 120 128	168 174 178 180	148	156 160	123 125 127	200 210 243	242 246	214 221 225	183 189 192 196
EM_17_06_M. sikkimensis	114 137	103 107 119	101 109 125	108 110 126 131	174 186 199	146 202	- -	119 127 131	205	220	206 212 214	189 198
EM_17_08_M. soulardii	104 126	80 88	113 131	108 110 126	182 208	170 176	140 153	137 150	196 229	244 246	204	196
EM_17_10_M. sublobata	106	88 101	105 135	114 130	174 184	148 170	148	125 137	200 222	226 230	212 254	192 200
EM_17_12_M. toringo	135 137	102 103	107 113	116 126	174 182	148 182	138 152	123 139	200 226	232 250	214 254	192 220
EM_17_14_M. toringoides	104 110 124 137	86 103	99 107 109 115	108 114 118 120	166 168 188	146 148 170	147 196	131 143 158	210 224 231 241	244 251	206 214	173 189 190 196
EM_17_19_M. transitoria	- -	103 111	117 127	122	178	148 184	162	123 133	200 202	256	221 231	194 200
EM_17_21_M. yunnanensis	126 140	98	117 121	108 120 124	162 182	206 208	- -	135 143	204 212	232 248	206	212 222
EM_A_01_M1 (E)	114 120 129	96	127 129	110 116	172 203	136 158	147	139 143	229 235	254	210 228	173
EM_A_03_M2	106 110	96 101	109 117	114	186 203	158 170	148 151	137 143	212 214	232 254	210 216	196 220
EM_A_05_M3	112	96	113 119	116 114	168 170	136 158	138 160	139	216 229	232 254	210 224	173 200
EM_A_07_M4	96 106	96 113	115	116	168 203	136 170	182	152 154	216 233	244 248	210 254	196
EM_A_08_M4	96 106	96 113	115	116	168 203	136 170	182	152 154	216 233	244 248	210 254	196
EM_A_09_M5	106 112	96	109 113	114 116	168 203	158	138 151	131 137	214 235	232 236	210 254	196 220
EM_A_10_M5	106 112	96	109 113	114 116	168 203	158	138 151	131 137	214 235	232 236	210 254	196 220
EM_A_11_M6	114 120 129	101 107	121 129	110 116	170 172	158 170	147	139 143	216 235	244 254	210 222	173
EM_A_13_M7	104 106	96 101	117 119	106 110	168	160 176	147	147 150	229 233	242 244	250 252	196 208
EM_A_15_M8	96 106	96	113 121	114 116	168 170	158	160 182	139 143	214 216	232 244	210 212	200 220
EM_A_21_M10	106 110	88 96	113 129	106 114	170 178	136 170	138	133	205 229	244	210 224	208 216
EM_A_23_M11	106	88 96	111 115	106 116	170 182	176 178	148 153	133 154	216 233	254 256	212 228	173
EM_A_25_M12	106 112	88 101	115 121	116 118	168 178	136 160	138 148	131 143	224 231	244 256	228 254	216 218
EM_A_26_M12	106 112	88 101	115 121	116 118	168 178	136 160	138 148	133 143	224 231	244 256	228 254	216 218
EM_A_27_M13	106 120	88 96	111 129	106 114	170 205	136 170	161	131 137	216 229	244 250	224	200 208
EM_A_29_M13 F	106 120	88 96	111 129	106 114	170 205	136 170	161	131 137	216 229	244 250	224	200 208
EM_A_31_M14	96 110	96 101	113	114 116	168 170	160 170	148	131 135	224 226	232 254	210 254	173 216
EM_A_33_M15	96 120	96	113 119	116 120	172 186	170	148	131 139	224 229	232	210 224	173 216
EM_A_35_M16	106 120	96 101	111 113	116 118	170 178	160 170	160	131	229 231	244	224 254	173 216
EM_A_37_M17a	106 112	96	109 113	114 116	168 203	158	138 151	131 137	214 235	232 236	210 254	196 220
EM_A_39_M18	96 133	88 96	117 125	114	186 205	170	150	131 139	229 231	232	210	173 200
EM_A_41_M19	96 133	88 96	117 125	114	186 205	170	150	131 139	229 231	232	210	173 200
EM_A_43_M20	96 110	96 100	111 113	114 116	168	158 178	148 182	139	216 224	232 238	210 216	220 222
EM_A_45_M21B	106 114 129	96 113	113 115 119	116	168 203	158 170 176	148 182	143 150 152	216 229 233	232 242 244	210 240 254	196
EM_A_49_M23	106 110	96	113 129	116	182 186	136 170	147	125 133	229	244 248	224	173 216
EM_A_51_M24	106 133	88 96	117 129	110 116	178 182	170	148 153	131 137	205 235	232 256	210 254	173 208
EM_A_54_M25	106 110	96	109 129	114 116	182 186	170 178	147	137	205 214	232	216 248	208 220
EM_B_01_M26	106	96 101	111 113	116 118	168 178	158 160	157 160	131 139	214 229	244	212 224	173 196
EM_B_03_M27	114 120 129	88 113	119 129	114 116	170 205	170	148	131 139	216 233	244 250	212 224	208 220
EM_B_05_MM101	106 120	88 96	103 127	116	182 203	158 170	147	143	205 229	244 254	210 248	173 208
EM_B_07_MM102	106 114 129	96	127 129	116	182 203	136 170	147	139 143	205 229	232 254	210	173
EM_B_09_MM104	106 110	88 101	103 117	114 116	182 186	170 178	148 151	137 143	205 214	232	210 216	173 196
EM_B_11_MM105	106 110	88 101	103 109	114 116	182 186	170 178	148 151	137 143	205 214	232	216 248	196 208
EM_B_14_MM106	110 114 129	96	129	116	172 180	136 170	148	139 143	205 229	244 254	210 228	173
EM_B_15_MM109	106 110	96	103 109	114 116	182 186	170	148	137	205 214	232 254	210 248	173 220
EM_B_17_MM110a	110 114 129	96	103 129	110 116	182 203	158 178	148	137 141	205 229	244 254	210	173

