APRC

Final Project Report

Project Title:	**Selection, evaluation and development of new apple and pear rootstocks in the UK**
Project Code:	**SP123**
Contractor:	**Horticulture Research International – East Malling**
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Duration:	**APRC 1 year (2000/2001)** **EMTHR 6 years**

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1: Background to the project:

1.1. History of rootstock breeding, selection and use

Apple scion varieties are difficult to propagate by vegetative (clonal) methods and do not come true-to-type from seed. Consequently, rootstocks have been used for propagating apples and pears for at least 2000 years. For most of this time rootstocks raised from seed or from suckers growing beneath trees were used. However, in the last 200 years clonal rootstocks, which are propagated by vegetative methods, have become much more popular and are now used in most countries producing apples and pears commercially. Potentially, clonal rootstocks offer many advantages compared with seedling rootstocks. They give uniform rather than variable performance when budded/grafted with scions and can also provide a whole range of other benefits (see below).

1.1.1 The rootstock Breeding Programme at HRI-East Malling

Apple: At the turn of the century the existing clonal rootstocks for apples had become very mixed up in nurseries in Europe. Work conducted by Hatton and others at East Malling resulted in these mixtures being sorted out and the first range (M.1 to M.9) of what came to be known as the Malling series of apple rootstocks were distributed. Subsequently, scientists at East Malling, either alone or in collaboration with scientists at the John Innes Institute, began making crosses between existing rootstocks and other *Malus* scions or selections, with the objective of producing an improved range of apple rootstocks. By the 1960s a range of useful apple rootstocks (M.27, M.9, M.26, MM.106, MM.111 and Merton 793) had been produced and these have continued to be used extensively throughout the world since their release.

Rootstock breeding has continued at HRI-East Malling since the 1960s, albeit at a reduced rate to the earlier years. The priorities have changed over the years but have usually included the following objectives:

- 1. Rootstocks of a range of vigour potentials, which induce increased precocity and abundance of yields in the scion variety
- 2. Rootstocks providing tolerance or resistance to soil-borne pests and diseases
- 3. Rootstocks inducing improved fruit size and quality

The breeding and preliminary screening of new HRI rootstocks for apples is currently funded as part of the Apple and Pear Breeding Club

Pear: As with apples, the traditional rootstocks used for pear propagation were seedlings of the scion species (i.e. *Pyrus communis*). Originally, seedlings from wild pears would have been used but for many decades in the 20th C the choice has usually been seeds extracted from commercial pear varieties such as ‘Winter Nellis’ or ‘Packham’s Triumph’. Such rootstocks impart strong vigour to the scion and induce very poor precocity in the scion.

In the 1920s, scientists at East Malling began seeking improved rootstocks for pear. This work led eventually to the release of two quince (*Cydonia oblonga*) rootstocks QA and QC (often referred to abroad as EM or Malling A and C). For UK growers producing mainly Conference or Comice, these rootstocks have performed quite well.

However, they are graft incompatible with many other pear varieties and a bridging interstock is needed to overcome this problem.

Breeding and selection of rootstocks for pears has continued at HRI-East Malling in recent years. The objectives have been the following:

- A quince rootstock which is more dwarfing than QC.
- A quince rootstock which induces improved fruit size and/or quality
- A *Pyrus* rootstock which not only shows improved graft compatibility with pear scions but which is also dwarfing, easy to propagate and which induces precocious and abundant yields of high quality fruits.

The breeding and preliminary screening of new HRI rootstocks for pears is currently funded as part of the Apple and Pear Breeding Club

1.1.2 Rootstock breeding and selection in other countries

Apple: Although the original Malling and Malling Merton range of rootstocks have proved satisfactory for use in most UK environmental conditions, the stocks are not fully suited to climatic or soil conditions in many other apple producing countries. A particular problem has been the need for improved tolerance to winter cold, drought and specific soil-borne pests and diseases. This unsuitability has prompted fruit breeders in many countries to initiate their own apple rootstock breeding programmes with the aim of producing rootstocks with specific new attributes.

Many of these new rootstocks have been released in recent years and UK growers are now frequently offered trees for sale on these new stocks. Often this promotion is made without any evidence that these new selections have any benefits or disadvantages in UK environmental conditions. The aim of this project has been to test objectively in UK conditions the most promising of these new selections.

Pear: Breeders of pear rootstocks in Western Europe have, focused mainly on selecting improved quince rootstocks. Three clones, in addition to QA and QC, have been widely available in commerce for many years; these are Adams, Sydo and BA.29 (Provence). However, quince stocks show poor compatibility with many pear scion varieties and are unsuited to certain environmental conditions (sensitive to severe winter cold, drought and high pH soils). Fruit breeders in the USA and in central Europe have, therefore, sought to select rootstock clones of the European edible pear species, *Pyrus communis*. These *Pyrus* stocks should, ideally, be capable of dwarfing pear scions grafted onto them and also have the other rootstock merits of quinces (precocious cropping, ease of propagation, good fruit size) but without the known disadvantages of the latter. Some of these selections are now becoming available from European nurseries, often in the absence of any objective evaluation in the UK. One objective of this programme of research has been to test the most promising of these rootstocks in UK conditions.

1.2. Benefits of Rootstock Use

Traditionally, rootstocks were used only to aid the propagation of scion varieties. However, it was soon realised that, by choosing certain selections, rootstocks could confer many more benefits to the scion and aid the grower in his/her objective of profitable fruit production. Some of the many advantages conferred to the scion by use of an appropriate rootstock are listed below:

- Control of scion vigour and tree habit
- Induction of precocious cropping
- Induction of abundant and consistent cropping
- Induction of large fruit size
- Resistance/tolerance to damaging soil-borne pests (e.g. woolly apple aphid and nematodes)
- Resistance/tolerance to damaging soil-borne pathogens (e.g. collar/crown rot)
- Tolerance to transient drought
- Tolerance to temporary anaerobic soil conditions
- Resistance/tolerance to very low winter temperatures

Once the major agronomic or environmental constraints on apple and pear production have been identified and prioritised for a particular site, it should be possible to overcome most of them by choice of an appropriate rootstock

1.3. Future Needs in Rootstocks

In recent years, there have been changes in the environmental and economic factors influencing UK apple and pear production. More than ever in the past, rootstocks are needed that induce precocious and very abundant cropping of large high quality fruits. Yields of the 'commodity' scion varieties of apple and pear are usually lower in the UK climatic conditions, compared with our competitors in southern Europe, and rootstocks, which can partly overcome this disadvantage, would be of immense benefit to commercial growers.

The consumer demand for reduced use of pesticides in the production of tree fruits and the move towards more organic growing systems is also stimulating changes in rootstock requirements. Most of the currently favoured dwarfing apple and pear (i.e. quince) rootstocks show poor tolerance of weed competition and the associated transient drought conditions common on many soils. Reduced water availability for irrigation, in counties such as Kent is likely to exacerbate this problem. Dwarfing rootstocks with better drought tolerance are undoubtedly needed for the future. Reductions in pesticide usage in the future will also prevent the use of soil fumigants and dwarfing rootstocks resistant to SARD and root rotting fungi, such as *Phytophthora cactorum* will also be required.

2. Aims of the Project:

The programme of work had two main objectives:

Objective A: Evaluation in the UK of apple and pear rootstocks obtained from breeding and selection programmes operating overseas

Objective B: Trialling, and development of apple and pear rootstocks produced as part of the HRI breeding programme and initially screened in trials funded by the Apple and Pear Breeding Club

3. Materials and Methods

3.1. Objective A: Evaluation in the UK of apple and pear rootstocks obtained from breeding and selection programmes overseas

The orchard trials conducted on apple rootstocks from abroad can be divided into three categories:

- *3.1.A.1 Trials of apple rootstocks raised by fruit breeders abroad, which were begun many years ago and grubbed in the early 1990s, but which have been written up and communicated to UK growers in more recent years.*

- *3.1.A.2 Trials of foreign apple rootstock, which are either still in the ground, or which were grubbed in 2000.*

- *3.1.A.3 Trials of pear rootstocks raised by fruit breeders in other countries*

3.1.A.1 Trials of apple rootstocks raised by fruit breeders abroad, which were begun many years ago and grubbed in the early/mid 1990s, but which have been written up and communicated to UK growers in more recent years.

The trials conducted as part of 3.1.A.1 are shown in Table 1:

Table 1. Description of trials conducted between 1980 and 1994 on apple rootstocks obtained from fruit breeders in countries other than the UK

Trial No. and Scion Variety	Rootstocks	Origin	Control rootstock	Replicates	Dates	
					Planted	Grubbed
1 Queen Cox	P.2, P.16, P.18, P.22 Bud.(B)9, Bud.146 MAC(9) (MARK)	Skierniewice, Poland Michurin Institute, Russia Michigan, USA	M.27 M.9 MM.106 MM.111	10 10	1983	1994
4 Queen Cox (3 trials)	M.9 clone: T.337, T.338, T.339, T.340 Nic. 4,10,13,14,16,19 22,25,27,29 SP.1(719), SP.2, SP.10(984) SP.18(751) INRA 71/0, Pajam 1, Pajam 2 M.9A	 NAKB, Holland Nicolai Nursery,Belgium Burgmer Nursery, Germany Ctifl, France HRI-EM, UK	EMLA-M.9	6 9 10	1980 1983 1987	1989 1990 1994

The Polish P. rootstocks included in the first mentioned of these trials (Trial 1) were produced at the Skierniewice Institute in Poland. The main objective of the breeders based there was to produce rootstocks with strong resistance to winter cold injury and with a range of vigour control. Their P. Series rootstocks were produced by crossing M.9, M.11, M.4 and M.8 with winter cold tolerant scion varieties and rootstocks, such as Antonovka, and Longfield. P.2, P.16, and P.22 are all now available through commercial nurseries in France and Holland.

The two Russian rootstocks tested Bud. 9 (B.9) and Bud. 146, raised at the Michurin Institute, were also selected to show improved winter cold tolerance. Bud 9 has gained some popularity in Poland and the USA as well as in Russia. Both clones were produced by crossing M.8 with the cold tolerant variety 'Red Standard'

MAC.9, which was subsequently named Mark, was selected at Michigan State University in the USA from open-pollinated M.9. It was widely available in Europe in the early 1990s but has since lost some of its early popularity following unfavourable reports on its performance in Washington State, USA.

The traditional EMLA sub-clone of M.9 has proved difficult to propagate for many European nurserymen, who have demanded easier to propagate sub-clones of this popular rootstock. In Holland, Belgium, France and Germany, nurserymen, sometimes aided by researchers, have sought to select easier-to propagate sub-clones of M.9. Several trials shown in Table 1 (Trials 2-4) were designed to compare the orchard performance of trees raised on these various M.9 sub-clones. Many of these sub-clones are available to UK growers via continental nurserymen.

3.1.A.2 Trials of foreign apple rootstock, which are either still in the ground, or which were grubbed in 2000.

The trials conducted as part of 3.1.A.2 are shown in Table 2

In Trial 5, the rootstocks from the Czech Republic were raised by crossing M.9 with local Czech varieties that were known to have good tolerance to winter cold. Jork (J).9 was raised at the Jork Institute in Northern Germany from open pollinated M.9. Bemali was raised at Balsgard in Sweden from a cross between Mank's Codlin and M.4. P.1 and P.60 are two further selections from the programme based at Skierniewice in Poland (see above). These stocks are available from selected continental nurseries. In this trial, trees receiving trickle irrigation in their establishment years were compared with trees with no irrigation.

In Trial 6, rootstock selections obtained from a breeding programme based at Cornell University, Geneva, New York State, USA are compared. These rootstocks, some of which are now becoming available commercially in Europe, were bred to provide improved resistances to winter cold injury, fire blight, woolly apple aphid, crown rot and tomato ringspot virus.

Table 2. Description of recent trials conducted on apple rootstocks obtained from fruit breeders in countries other than the UK

Trial No. and Scion Variety	Rootstocks	Origin	Control rootstock	Replicates	Dates	
					Planted	Grubbed
5 Queen Cox	J-TE-E, J-TE-F, J-TE-H Jork (J) 9 Bemali P.1, P.60	Czech Republic Jork, Germany Balsgard, Sweden Skiernewice, Poland	M.27 M.9 M.26 MM.106	6	1994	2000
6 Queen Cox	G.11, G.30, G.902 G.730, G.202, G.210 G.179	Geneva Experimental Research Station, New York State, USA	M.9 MM.106	5	1995	Extant
7 Mondial Gala	V.1, V.3, V.4	Vineland (Simcoe) Research Institute, Canada	M.9 Pajam 2	5	2000	Extant

The Vineland series rootstocks recently planted in Trial 7 were also bred to provide improved cold tolerance, but have also performed well in less severe conditions on some USA sites.

3.1.A.3 Trials of pear rootstocks raised by fruit breeders in other countries

The trials conducted on rootstocks for pears obtained from fruit breeders overseas are shown in Table 3

The *Pyrus* selection Pyrodwarf, which is included in trials 8 and 9 was selected at the Geisenheim Research Station in Germany from seedlings of 'Bonne Louis d' Avranche'. The initial reports from Germany indicate that this clone is dwarfing, easy to propagate, resistant to winter cold, fire blight and drought. It is also said to induce precocious and abundant cropping. These very favourable reports have stimulated demand for the stock on a large scale in the USA in the last few years. However, no tests have been completed on Pyrodwarf outside of Germany to date and the initial German tests were not very extensive.

BP1 was bred in South Africa many years ago, where it was reported to produce trees of intermediate vigour. Trials have now been conducted in several countries in Southern Europe and also in Holland.

The quince rootstock Sobu compared with Pyrodwarf in Trial 9 is a selection obtained by Dutch colleagues who have planted a mirror image of this trial at Randwijk in the Netherlands. The other stocks compared in this trial, all *Pyrus*, are pear scion varieties being evaluated as potential rootstocks.

Trial 10 compares rootstocks in the Brossier series. These dwarfing clones of *Pyrus* originate from seedlings of Perry pears and were selected at Angers, in France many years ago. They proved dwarfing and productive in the initial French trials but are very difficult to propagate and have not yet, therefore, been developed commercially. The establishment and initial three years following planting of this trial was greatly aided by funds provided by the Washington State Tree Fruit Research Commission. For this reason, Williams was used as one of the scion varieties in the trial.

Table 3. Description of trials in progress, comparing quince or *Pyrus* rootstocks for pears obtained from fruit breeders in other countries other than the UK

Trial No. and Scion Variety	Rootstocks		Origin	Control rootstock	Replicates	Date Planted
	Species	Clone				
8 Comice Conference	*Pyrus* *Pyrus*	Pyrodwarf (Rhemus 1) BP.1	Geisenheim, Germany Stellenbosch, South Africa	QC QC	5	1997
9 Conference Comice	*Pyrus* *Pyrus*	Pyrodwarf Sobu	(see above)	QC		2000
10 Comice Williams	*Pyrus* *Pyrus* *Pyrus* *Pyrus*	RV.113 RV,134 RV.139 G.28-119	INRA, Angers, France	QC QA Farold OHxF.69	10	1997

3.2 Objective B: Trialling, and development of apple and pear rootstocks produced as part of the HRI breeding programme and initially screened in trials funded by the Apple and Pear Breeding Club

3.2.B.1 Trials of apple rootstocks selected in preliminary screening trials by the Apple and Pear Breeding Club

Apple rootstocks produced by the fruit breeding team at HRI-East Malling are tested initially in small screening trials, usually with Queen Cox as scion. Over the past 15 years 11 screening trials have been run; 5 of these are still in existence. Any rootstock clones showing promise in these trials, in terms of their effects on yield efficiency, fruit size or disease resistance (collar rot), have been retained for further evaluation.

The most promising HRI rootstock selections are as follows:

Rootstocks with similar vigour to M.27:
AR.69-7, AR.628-2, AR.672-1, AR.682-6

Rootstocks with vigour intermediate between M.27 and M.9
AR360-19, AR.486-1, AR.669-1

Rootstocks with similar vigour to M.9
AR.680-2, AR295-6, AR.120-242

Rootstocks with vigour similar to M.26
AR.801-11

Rootstocks with vigour similar to MM.106
AR.86-1-25, AR.86-1-20, AR.10-3-5

Propagation tests have been conducted on most of these selections under a project previously funded by the EMTHR. The next objective, the raising of sufficient trees for grower trials has been hampered by factors outside the control of the project supervisor. Unfortunately, rootstocks sent to commercial nurseries in the UK for bulking up more than 5 years ago were lost and only recently have the first few trees for further testing of these stocks been raised.

3.2.B.2 Trials of pear rootstocks selected in preliminary screening trials by the Apple and Pear Breeding Club

The trials on HRI-East Malling pear rootstocks, which are fully or partially funded under this project, are shown in Table 4. In almost all the trials, the quince selections QA and QC are used as controls.

Trials 11 and 12, which are planted at HRI-East Malling and the four grower trials (Trials 16-19) focus on the development of a new quince selection QR.193-16. This selection, which showed promise in a screening trial completed several years ago, is also being tested in trials in France, Italy and Spain. Trial 11 compares QR.193-16 with three other quince selections when used as rootstocks for Comice and Concorde. Trial 12 compares Conference on

QR.193-16 and QC when the trees are raised with different heights of budding. Previous trials on dwarfing apple and quince rootstocks have shown that increasing the height of budding can, in some instances, increase the degree of scion dwarfing achieved. The aim of the grower trials of QR.193-16 is to evaluate its performance in different soil and climatic conditions in the UK.

Trial 13 is focused on further testing of several HRI *Pyrus* rootstock selections. The QR.708 selections were raised by crossing the scion variety Old Home with BP.1, the semi-dwarfing *Pyrus* rootstock originating in South Africa. QR708-36 and 708-2 are also being evaluated in French trials. QR 517-9 is another HRI-East Malling selection, which has shown strong resistance to fire blight in previous tests. Also included in this trial are two *Pyrus* selections from the French Brossier series, RV.113 and G.28.119. A further objective of this trial was to compare the performance of some of these clones when raised either by conventional cutting or micropropagation techniques. For the first 4 years of its life, this trial was funded primarily by the Washington Tree Fruit Research Commission. For this reason, the variety 'Williams'was used as the principal scion variety.

A very small trial, (Trial 14), and also Trial 15 focus on evaluating the quince rootstock selection C.132. Trials in Holland have indicated that this HRI selection is slightly more dwarfing than QC. In this trial a dwarfing *Pyrus* selection from the Swedish (Balsgard) breeding programme, BP30 is also included.

Table 4. Description of trials in progress, comparing quince or *Pyrus* rootstocks previously selected in screening trials as part of the Apple and Pear Breeding Club

Trial No. and Scion Variety	Rootstocks		Origin	Control rootstock	Replicates	Date Planted and Site
	Species	Clone				
13 Conference Williams Comice	*Pyrus* *Pyrus*	QR.708-36 QR.708-2 QR.708-13 QR.517-9 RV.113 G.28-119	HRI-EM HRI-EM HRI-EM HRI-EM INRA, France INRA, France	QA QC		1996-EM
14 Conference	*Pyrus* Quince	QR.708-2 C.132	EM EM	QC		1997-EM
15 Comice Conference	Quince	BP30 C.132	Balsgard, Sweden EM	QC		1999-EM
11 Comice Concorde	Quince	QR.193-16 (EM.H) QR.193-2	EM	QC QC		1990-EM
12 Conference	Quince	QR.193-16 (EM.H)	EM	QC		1994-EM
16-19 Conference Concorde	Quince	QR.193-16 EM.H)	EM	QC	variable	1998-Kent 1, Kent 2, W. Midlands, Suffolk

Results:

4.1 Objective A: Evaluation in the UK of apple and pear rootstocks obtained from breeding and selection programmes overseas

4.1.A.1 Trials of apple rootstocks raised by fruit breeders abroad, which were begun many years ago and grubbed in the early 1990s, but which have been written up and communicated to UK growers in more recent years.

Trial 1

Details of the results of Trial 1, which compared several Polish and Russian selections with Mark and the standard Malling and Malling Merton stocks are presented in an attached research paper: ' Apple rootstock studies: L Comparison of Polish, Russian, USA and UK selections as rootstocks for the apple cultivar Cox's Orange Pippin (*Malus domestica* Borkh.)'. The merits and problems associated with each of the new rootstocks are listed below. These summaries take account of results from other trials conducted abroad, as well as the East Malling results.:

P.2 In the East Malling trial vigour of Cox on P.2 was intermediate between vigour on M.27 and M.9. However, on sites in Holland and with trickle irrigation tree vigour on this rootstock is likely to be much closer to that of M.9. Trees should be planted with the rootstock union close to the soil surface if burrknotting and suckering are to be minimised

P.16 Vigour of trees on P.16 is similar to that on M.9. The stock, which has similar sensitivity to winter cold damage to M.9 (cf. Other Polish stocks), induces excellent yield precocity and yield efficiency. Trees should be planted with their unions as close as possible to the soil surface to reduce the tendency to burr knotting and suckering. The stock is quite sensitive to drought.

P.18 A very invigorating rootstock which has no advantages and several disadvantages (e.g. poor induction of yield precocity) compared with MM.111.

P.22 Trees on this stock planted in the un-irrigated East Malling trial were stunted and grew more poorly than trees on M.27. However, in some trials abroad on very deep soils with trickle irrigation provided, vigour on this stock is intermediate between M.27 and M.9. Fruit size was small on this stock at East Malling and similar effects have been noted in the USA. Trees should be planted with the rootstock union close to the soil surface if burrknotting and suckering are to be minimised. Clones of P.22, differing slightly in their vigour and rootstock performance, are now available in mainland Europe. Irrigation and good soil depth and fertility are essential if this stock is chosen.

Bud (B)9 Vigour of trees on B.9 in the East Malling trial was similar to vigour on M.9 and Mark. When grown on deeper more fertile soils in other parts of the world, vigour is often closer to that on M.26. Yield efficiency in most trials is slightly inferior to that achieved on M.9. Has value as a cold tolerant rootstock or interstock in areas experiencing very severe winter temperatures. Recent observations in the USA indicate that trees on B.9 suffer less severely from fire blight attacks than trees on M.9 and most other rootstocks tested.

Bud 146 Trees on B.146 were very weak and performed poorly in the East Malling trial. On better soils and with irrigation Dutch results show B.146 to be of similar vigour to M.27. Yield efficiency is very good on this rootstock although fruit size may be reduced.

Mark Vigour of Cox on Mark planted in the East Malling trial was very similar to vigour on M.9. However, the rootstock is very sensitive to drought conditions and on hot dry soils very small poor quality trees are produced. In contrast, on deep fertile soils with irrigation tree vigour is more similar to that on M.26. Although there are some reports of increased yield efficiency on Mark, this effect is not consistent from site to site. Mark invariably produces a large swelling on the trunk, either just above aor just below the soil surface. The causes and implications of this anomaly have never been fully researched.

Trials 2-4

Detailed results of the three trials conducted to compare the orchard performance of various M.9 clones are shown in the publication: 'Orchard comparisons of 'Cox's Orange Pippin' grown on selections of the apple rootstock M.9'Brief notes summarising the attributes of the clones available commercially in Europe are presented below:

Pajam 1 This French virus-free clonal selection of M.9 is very slightly more dwarfing than the EMLA selection of M.9 (5%-10%). Yield precocity and yield efficiency are similar on Pajam 1 and EMLA M.9. Pajam may be a better choice than EMLA-M.9 where slightly reduced vigour is desired, as with certain triploid varieties.

Pajam 2 Another French selection of M.9, which is very similar in performance to EMLA-M.9. It would appear to offer no advantages or disadvantages to apple producers in terms of tree vigour and cropping when compared with the EMLA sub-clone.

Nicolai (K) 29 A sub-clone of M.9 selected in Belgium, which induces slightly greater scion vigour than EMLA-M.9. It is similar to the EMLA sub-clone in its effects on yield precocity and efficiency. A suitable choice of M.9 sub-clone where slightly increased vigour is needed in comparison with EMLA-M.9, such as on soils of reduced fertility or with scions of low inherent vigour.

T.337 The most popular Dutch sub-clone of M.9, which induces vigour similar or occasionally slightly less than EMLA-M.9. As with most other M.9 sub-clones it induces similar yiel precocity and yield efficiency.

Burgmer sub clones 719, 751 or 984 In the East Malling trials these sub-clones usually induced slightly increased vigour compared with EMLA-M.9. It is important to ensure that a virus-free source is guaranteed, if choosing trees on these sub-clones.

4.1.A.2 Trials of foreign apple rootstock, which are either still in the ground, or which were grubbed in 2000.

Trial 5

The final size of the trees in Trial 5, which compared rootstocks raised in the Czech Republic, Germany, Sweden and Poland with the conventional Malling and Malling Merton rootstocks, is shown in Table 5.

The total cumulative yields 1995-2000 in this trial and the yield efficiencies are shown in Table 6, whilst the yields of Class I (>65 mm diameter) fruits are shown in Table 7.

Irrigation applied in the first years of the trial increased the final size of trees (as measured by trunk girth) on most of the rootstocks. However, trees on J.9 showed no such response to the irrigation and the effects on trees on M.27, M.9, M.26 and MM.106 were all very small. This suggests that, although some of the stocks are very sensitive to water shortages, others including many of the traditional Malling rootstocks are less sensitive.

The advantages and disadvantages of the new rootstocks are as follows:

J-TE-E The Cox trees on the Czech rootstock J-TE-E were smaller than trees on M.9 and when not irrigated were only slightly larger than trees on M.27. However, the trees were a little larger when irrigated. Yield efficiency (yields in relation to tree size) on J-TE-E was very good and equal to M.9. The percentage of Class 1 (>65 mm diameter fruits) was also very good and better than that on M.9. This Czech stock warrants more extensive testing.

J-TE-F Trees on J-TE-F were intermediate in size between trees on M.27 and M.9.This stock also responded quite positively to trickle irrigation. Yield efficiency (yields in relation to tree size) on J-TE-F was very good and slightly better than for M.9 where no supplementary irrigation was applied. The percentage of Class 1 (>65 mm diameter fruits) was also very good and better than that on M.9. This Czech stock warrants more extensive testing.

J-TE-H Trees on this rootstock were slightly larger than those on M.26 but of less vigour than trees on MM.106. Yield efficiency (yields in relation to tree size) on J-TE-H was poorer than on M.9 and more similar to the efficiencies shown by M.26 and MM.106. The percentage of Class 1 (>65 mm diameter fruits) was also very good for irrigated trees but relatively poor where no irrigation was applied.

Jork 9 Trees on Jork 9 were either of M.26 size or larger. Unusually, the largest trees were ones receiving no irrigation; this effect is not understood. Yield efficiency (yields in relation to tree size) on Jork 9 was very good on the irrigated trees but poorer on trees not irrigated. The percentage of Class 1 (>65 mm diameter fruits) was, however, poor for trees on this rootstock. This German stock warrants more extensive testing in organic systems where its apparent drought tolerance may prove useful.

Table 5. Final size of Queen Cox trees in 2000, which were planted as maidens on 11 different rootstocks in 1994.

	Crown Volume (m^3)		Trunk Girth	
Rootstock	Irrigated	Non Irrigated	Irrigated	Non Irrigated
J-TE-E	14.3	11.1	18.7	15.5
J-TE-F	22.2	19.8	20.3	17.1
J-TE-H	30.5	30.0	24.9	23.5
Jork 9	26.9	36.1	22.3	25.9
Bemali	30.8	20.4	23.2	19.5
P.1	27.5	29.4	25.3	22.9
P.60	26.4	29.1	23.9	21.6
M.27	6.8	8.9	14.8	14.5
M.9	26.3	22.0	20.9	20.1
M.26	26.2	27.1	22.5	22.8
MM.106	35.8	38.0	23.4	23.4

Table 6. Total yields of Queen Cox trees which were planted as maidens on 11 different rootstocks in spring 1994

Rootstock	Total Cumulative Yields 1995-2000+		Yield Efficiency Total Cumulative Yields/trunk cross sectional area	
	Irrigated	Non Irrigated	Irrigated	Non Irrigated
J-TE-E	60.8	35.7	2.20	1.83
J-TE-F	69.2	48.9	2.17	2.07
J-TE-H	85.0	65.0	1.72	1.48
Jork 9	87.1	79.6	2.21	1.48
Bemali	85.6	51.8	2.01	1.74
P.1	94.6	65.1	1.84	1.62
P.60	81.1	75.3	1.84	2.03
M.27	36.5	37.9	2.20	2.28
M.9	75.9	59.2	2.21	1.85
M.26	61.9	62.4	1.59	1.52
MM.106	82.2	68.9	1.86	1.60

+ No yields in 1997 due to severe frost damage

Table 7. Yields of Class I (> 65 mm diameter) Queen Cox fruits on trees, which were planted as maidens on 11 different rootstocks in spring 1994.

Rootstock	Cumulative Yield 1995-2000 Class I (> 65 mm diameter)			
	Irrigated		Non Irrigated	
	Kg/tree	(% of total)	Kg/tree	(% of total)
J-TE-E	40.2	(66)	21.7	(61)
J-TE-F	47.7	(69)	27.6	(56)
J-TE-H	58.9	(69)	31.0	(48)
Jork 9	36.1	(41)	36.8	(46)
Bemali	44.9	(52)	24.8	(48)
P.1	43.7	(46)	27.5	(42)
P.60	49.4	(61)	38.1	(51)
M.27	20.4	(56)	17.1	(45)
M.9	42.7	(56)	28.3	(48)
M.26	37.5	(61)	39.5	(63)
MM.106	43.1	(52)	40.5	(59)

Bemali Where no supplementary irrigation was given, the trees on Bemali were of similar size to trees on M.9. However, with irrigation the trees were larger than those on M.26. Yield efficiency (yields in relation to tree size) on Bemali was good for irrigated trees and average/good for trees without irrigation. The percentage of Class 1 (>65 mm diameter fruits) was, however quite poor on this rootstock.

P1 P1 produced trees more vigorous than trees on M.26 but of less vigour than those on MM.106. Yield efficiency (yields in relation to tree size) on P1 was only average and similar to that on MM.106. The percentage of Class 1 (>65 mm diameter fruits) was relatively poor and significantly worse than on M.26.

P.60 Trees on P.60 were of similar size to M.26. Yield efficiency on P.60 was slightly better than on M.26. The percentage of Class 1 (>65 mm diameter fruits) was similar on P.60 and M.26 for irrigated trees but was poorer on P.60 where trees received no irrigation.

Trial 6

The current tree size, cumulative yields and yield efficiencies to date in Trial 6, which compares rootstocks of USA origin are shown in Table 8. The preliminary results indicate the following

Geneva To date, this rootstock has produced a tree similar in size to trees on M.9. Compared with other stocks in this trial it has induced good yield efficiency. Grade outs have been poor on the young trees in this trial and Geneva 11 has been average in this respect.

Geneva 30 The trees on Geneva 30 are similar in size to the trees on MM.106 but with lower cumulative yields and yield efficiencies. The proportion of Class 1 fruits produced on these trees is, to date only average in comparison with the other rootstocks in the trial.

Geneva 179 This stock is producing trees which currently are similar in size to trees on M.9. It has induced good yield efficiency and, in comparison with the other rootstocks, a good percentage grade out.

Geneva 202 Trees on G.202 are similar or slightly more vigorous than trees on M.9 currently. It has induced the best yield efficiency in this trial and average percentage grade outs of large, quality fruits.

Geneva 210 This rootstock has produced trees slightly larger in size to those on M.9. However, yield efficiency and fruit grade outs have been poor on this selection.

Geneva 730 This rootstock is the most dwarfing of the Geneva series compared in this trial; the trees are currently smaller than those on M.9. However, yield efficiency is poor to date and fruit grade out only average.

Geneva 902 This also produces trees slightly smaller than those on M.9. Yield efficiency has been very good and fruit grade out average.

Table 8. Size and yields of Queen Cox trees planted on Cornell-Geneva (USA) rootstocks in 1995

Rootstock	Trunk girth 2000/2001	Cumulative Yields 1996-2000			Yield Efficiency Cumulative Total Yield/tree
		Total	Class I (> 65 mm)	(% of total)	Trunk CSA in 2000/2001
G.11	19.5	42.9	22.3	(52)	1.43
G.30	23.9	57.3	25.4	(44)	1.25
G.179	19.0	36.2	20.9	(58)	1.28
G.202	20.0	44.3	22.3	(50)	1.46
G.210	20.4	32.1	13.4	(42)	1.02
G.730	15.0	20.6	10.7	(52)	1.12
G.902	16.7	32.6	16.4	(50)	1.48
M.9	19.5	32.3	12.9	(40)	1.08
MM.106	23.1	66.6	34.4	(52)	1.60

Two more years cropping data would consolidate the information gathered to date and help formulate objective assessments of these clones.

Trial 7

At the time of planting in March 2000 the tree quality of these bench grafts was very poor in comparison with the controls used on Pajam 2. Further years will be needed before meaningful assessments can be made.

4.1.A.3 Trials of pear rootstocks raised by fruit breeders in other countries

Trial 8

The shoot growth and tree size (trunk girth) of the Conference and Comice trees planted in this trial in 1997 are shown in Table 9.

The tree quality on Pyrodwarf at the time of planting was extremely poor, possibly indicating more problems with propagation than the German reports on this rootstock would suggest. In addition, information from a UK nursery is that Pyrodwarf is very difficult to layer and is mainly supplied from Germany via micropropagation. Although only one third the size of trees on QA and QC at the time of planting, the Conference trees on Pyrodwarf are now approximately similar in size to the trees on QC. The Comice trees on this stock are still smaller than the Comice trees on QA or QC, however.

The Conference trees on the South African selection, BP.1 have made similar or slightly less growth than trees on QC. However, many of the trees on BP.1 have died and others look very unhealthy. The suspected cause of death is the phytoplasma Pear Decline. Trials in Italy have shown recently that BP.1 is extremely sensitive to this problem.

The flowering and preliminary yields of trees in Trial 8 are shown in Table 10.

Although floral precocity was poorer on the trees on Pyrodwarf than on QC this may be partly explained by the smaller tree size in the first few years on this rootstock. By 2001 the numbers of flowers formed on Conference trees was still less on Pyrodwarf than on the QA and QC stocks. However, with the variety Comice, flowering on Pyrodwarf was equal to that on QA by 2001. The first yields on the trees were highest on QC but similar on the QA and the Pyrodwarf trees. Initial calculations of yield efficiency show QC trees best but Pyrodwarf and QA trees approximately similar.

Table 9. Shoot growth and trunk girth of pear trees on Pyrodwarf, BP.1, QA and QC rootstocks (trees planted in spring 1997)

Scion	Rootstock	Height of leader at planting (cm)	Total shoot growth 1996-1999 (m)	Trunk girth 2000 (cm)
Conference	Pyrodwarf*	34	17.2	11.9
	QC*	115	23.3	11.9
	QA*	111	23.0	13.2
Comice	Pyrodwarf*	37	27.2	12.0
	QC*	134	36.9	13.5
	QA*	143	31.8	13.8
Conference	BP.1+	-	19.4	12.2
	QC+	-	26.1	12.0

* One-year-old at planting
\+ Two-year-old trees at planting

Table 10. Floral bud numbers and initial yields of pear trees planted on Pyrodwarf, BP.1, QA and QC rootstocks in spring 1997

		Floral bud number/tree			Total yields/tree (kg)		Yield Class I	
Scion	Rootstock	1999	2000	2001	1999	2000	1999	2000
Conference	Pyrodwarf*	17	49	50	0.08	0.15	0.00	0.06
	QC*	74	98	81	1.96	0.98	0.32	0.37
	QA*	30	36	93	0.32	0.12	0.10	0.05
Comice	Pyrodwarf*	12	62	96	0.20	0.06	0.06	0.01
	QC*	28	75	126	1.20	0.23	0.84	0.04
	QA*	24	64	69	0.34	0.05	0.18	0.00
Conference	BP.1+	54	64	82	1.87	0.21	0.33	0.00
	QC+	94	93	108	2.12	0.77	0.64	0.26

* One-year-old at planting
\+ Two-year-old trees at planting

Trial 9

All the trees planted in this trial were two-year-old well-feathered trees. This was thought to be essential to compare Pyrodwarf and the other stocks included more objectively than in Trial 8 where the Pyrodwarf trees supplied from Holland were such poor quality.

The trial was planted only in the spring of 2000 and has provided only limited information, to date. Table 11 shows the best feathered trees at the time of planting were those on QC rootstock.

Extension shoot growth in the first year following planting and trunk girth in the winter of 2000/2001 were least for Conference trees on Sobu quince rootstock. Data in future years will be needed before this trial can provide meaningful results and conclusions.

Trial 10

Although considerable difficulties were experienced in propagating sufficient trees for this trial of the Brossier rootstocks from France, a small trial was established in spring 1997. However, only one tree of Williams on the most dwarfing selection RV139 was produced and this is best omitted from the comparisons. The preliminary results from this trial are shown in Table 12.

The largest Comice trees, currently, are those grafted on RV113, which are larger than trees on QA. However, this is not the case where Williams is the scion, where trees on RV113 and QC are of approximately similar vigour. Cropping of Comice on RV.113 has been less than on QC but more than on QA; fruit size has been similar on QA and RV.113 but smaller on QC. With the scion variety Williams, cropping and fruit size on RV113 has, to date, been similar to that on QC.

Tree vigour has been particularly weak on RV.134 and cropping and fruit size quite poor. Williams trees on G.28.119 rootstock are less vigorous than Williams on QC, with slightly reduced yields and similar fruit size.

The Old Home x Farmingdale (OHxF69) selection included in this trial has induced very strong vigour in the Williams trees and only average cropping and poor fruit size.

Table 11. Initial shoot growth and trunk girth of Conference and Comice trees planted on *Pyrus* and Quince rootstocks in spring 2000

Scion	Rootstock		Ht of leader at planting (cm)	No. of feathers	Total shoot growth (m) 2000	Trunk girth (cm) 2000	Floral buds/tree 2001
	Species	Clone					
Conference	Quercus	QC	61	12	6.2	8.2	14
		Sobu	81	3	1.6	6.7	5
	Pyrus	Gieser Wildeman	94	5	4.9	8.3	2
		Delbuena	84	5	6.2	8.1	1
		Dolacomi	71	7	6.3	8.2	1
		Pyrodwarf	85	6	5.4	8.3	2
Comice	Quince	QC	78	13	3.2	8.1	5
		Sobu	76	4	3.5	7.0	5
	Pyrus	Gieser Wildeman	77	7	3.0	7.2	0
		Delbuena	87	6	4.5	8.0	2
		Dolacomi	93	7	4.0	8.2	0
		Pyrodwarf	82	5	3.5	7.9	0

Table 12. Vigour of Comice and Williams pear trees planted on several *Pyrus* and Quince rootstocks in spring 1997

Scion	Rootstock		Total shoot growth in 2000 (m)	Trunk girth in 2000 (cm)	Total yield/tree (kg)		Wt of Class I >65 mm (kg) in 2000	Mean fruit wt (g) in 2000
	Species	Clone			1999	2000		
Comice	*Pyrus*	RV.113	13..9	15..5	1.3	1.6	1.0	260
		RV.134	1.0	8.2	0.3	0.2	0.1	115
		QA	8.6	14.6	0.9	0.8	0.4	272
		QC	5.4	12.6	2.1	1.9	1.1	215
Williams	*Pyrus*	RV.113	9.8	11.9	0.7	2.7	1.5	209
		RV.134	1.5	7.6	0.3	0.6	0.3	142
		RV.139+	0.7	6.2	1.4	0	0	-
		G.28.119	5.6	8.9	0.9	1.2	0.4	186
		OHF.69	50.9	16.0	0.2	3.6	1.6	153
		QA	18..8	13.5	0.7	3.7	1.9	184
		QC	9.5	10.9	0.7	2.6	1.0	197

+ only one replicate tree

4.2 Objective B: Trialling, and development of apple and pear rootstocks produced as part of the HRI breeding programme and initially screened in trials funded by the Apple and Pear Breeding Club

4.2.B.1 Trials of apple rootstocks selected in preliminary screening trials by the Apple and Pear Breeding Club

Following the abortive attempts described above to build up the promising apple rootstock clones first in commercial and then in the East Malling nursery, rooted liners were finally produced at HRI-East Malling of some of the clones in the winter of 2000/2001. Some of these rootstocks have been bench grafted in the winter of 2000/2001; others will be budded in August 2001. Finally, stocks of some of the clones have been sent to Mr. Maurice Sarson, with the objective of forming new layer beds. The details are shown in Table 13.

Table 13. Propagation plans for new HRI-East Malling apple rootstock clones

Rootstock	Vigour category	Bench grafted 2001 SFQ Cox*	Bench grafted 2001 Bramley	Bud in August 2001 Royal Gala	Bud in August 2001 Red Falstaff	Nursery (Maurice Sarson)
AR.486-1	M.9	43	-	168	-	73
AR.295-6	M.9	42	-	90	-	65
AR.120-242	M.9	50	-	25	-	0
AR.680-2	M.9	-	-	-	-	15
M.9	M.9	45	-	45	-	-
AR.628-2	M.27	-	75	-	67	22
AR.69-7	M.27	-	75	-	46	0
AR.360-19	M.27	-	12	-	6	0
M.27	M.27	-	75	-	45	-
AR.801-11	M.26	-	27	-	0	8

*Self-fertile Queen Cox

4.2.B.2: Trials of pear rootstocks selected in preliminary screening trials by the Apple and Pear Breeding Club

Trial 11

The tree vigour and cumulative yields of Comice and Concorde trees planted on two new quince selections and QA and QC are shown in Table 14.

The trees of both varieties grafted on QR.193-16 are intermediate in vigour between QC and QA, while vigour on QR.193-2 is similar to or greater than on QA. The cumulative total yields of Comice on QR.193-16 are less than on QC and yield efficiency is also less on QR.193-16. However, the cumulative yield of Class 1 large fruits is highest on this new

Table 14. Vigour of Comice and Concorde trees planted on four quince rootstock clones in spring 1990

Scion	Rootstock	Total shoot growth 1990-1996 (m)	Trunk girth 2000 (cm)	Total yield/tree 1994-2000+ (kg)	Total yield/trunk CSA in 2000	Cum.yield/tree Class I >65 mm++ (kg)
Comice	QR.193-16	99	29.4	49.1	0.72	19.2
	QR.193-2	160	32.1	49.6	0.62	17.5
	QA	136	31.3	51.6	0.69	18.7
	QC	83	27.3	54.4	0.92	18.2
Concorde	QR.193-16	36	24.5	41.9	0.88	13.2
	QR.193-2	48	27.5	40.3	0.66	9.9
	QA	47	27.5	38.2	0.64	10.9
	QC	31	23.4	37.5	0.84	8.0

\+ No yields in 1997 due to frost damage

++ Omits yields on Comice in 1995 and yield on both cvs. In 1997 rootstock selection. Cumulative total yields of the variety Concorde are highest on QR.193-16 and yield efficiencies for this scion are similar for QR.193-16 and QC rootstocks (both higher than for QA and QR.193-2). The cumulative yield of the largest Class I fruits is greatest on QR.193-16 and least on QC.

Trial 12

Table 15 shows that although increasing the height of budding reduced the vigour of trees on QC rootstock, no similar effect was achieved by high budding onto QR.193-16.

Cumulative yields for 1996 plus 1998-200 (omitting 1997 a frost year) were increased slightly by increasing the height of budding on QC but not on QR.193-16. As shown in previous trials, yields in the first few years following planting were poorer on QR.193-16 than on QC and this resulted in a depression in the cumulative yields up to 2000. This is reflected in the calculations of total yield per unit trunk cross sectional area. The poor performance of the QR.193-16 trees budded at 30 cm is not understood. However, comparisons of the cumulative yields of Class 1 fruits (>65 mm in diameter) on trees budded at 15 cm or 45 cm showed no differences between the two rootstocks. Measurements of fruit size showed much larger fruits produced by the trees on QR.193-16 and no consistent effect of budding height.

Trial 13

Several rootstocks included in this trial planted in 1996 are inducing lower vigour in the variety Williams than QA (Table 16).

The least vigour is shown by trees on G.28-119, a selection from the French Brossier series and QR.517-9 a fire blight resistant selection from the HRI-East Malling programme. All of the trees on the various QR.708 series are currently of similar or slightly less vigour than trees on QA rootstock. With two of the stocks QR.708-2 and QR.708-13 tree vigour is greater where rootstocks raised by micropropagation are used rather than rootstocks propagated by conventional cutting techniques. One stock QR.708-23 shows no similar effect of micropropagation.

Table 15. Influence of height of budding on the vigour and cropping of young Comice trees on QR.193-16 and QC rootstocks (trees planted in 1994)

Rootstock	Rootstock		Trunk girth 2000 (cm)	Cum yield (kg/tree)+ 1996-2000	Cum. Total yield/trunk CSA in 2000	Cum. Yield Class I >65 mm (kg/tree) 1996-2000	Mean fruit wt (g) in 2000
	Height of budding	Cum. Shoot growth (m) 1994-1999					
QR.193-16	15	122.6	21.6	15.2	0.41	7.0	201
	30	143.4	20.9	9.0	0.26	4.0	219
	45	140.5	21.2	17.2	0.49	11.0	215
QC	15	113.6	21.3	16.4	0.45	6.3	148
	30	114.7	19.7	22.6	0.75	10.7	141
	45	93.6	18.1	23.2	0.90	12.0	138

+ no yields in 1997 due to frost

Table 16. Vigour and yields of Williams pear trees planted in spring 1996 on *Pyrus* and Quince rootstocks

Species	Rootstock		Total shoot growth/tree (m) 1997-1999	Trunk girth (cm) 2000	Total yields/tree (kg)	
	Clone	Method of propagation			1999	2000
Pyrus	QR.708-2	Conventional	46.0	14.7	1.3	1.5
	QR.708-2	Microprop.	75.6	16.2	1.4	2.0
	QR.708-13	Conventional	37.0	12.9	1.7	4.1
	QR.708-13	Microprop.	57.8	14.1	2.0	4.5
	QR.708-23	Conventional	74.3	15.5	1.1	2.8
	QR.708-23	Microprop.	59.2	15.5	1.6	4.0
	QR.708-36	Conventional	68.6	15.2	6.1	6.8
	QR.517-9	Microprop.	34.3	10.4	0.4	2.4
	G.28-119	Microprop.	16.3	11.3	2.2	0.9
	RV.113	Microprop.	49.3	14.8	4.1	3.5
Quince	QA	Conventional	68.0	17.9	1.7	3.7

The best yields by far in 1999 and 2000 have been harvested from trees on QR.708-36, which of approximately similar vigour to QA. Trees on the French stock RV.113 also yielded well in both years. Promising yields were also harvested from trees on QR.708-13 and to a lesser extent QR.708-23 in 2000.

This trial also includes trees of the variety Conference, but unfortunately no controls of this variety on QA or QC. Nevertheless, as shown in Table 17, Conference on QR.708-36 have yielded much better than trees on other selections in this series. Tree vigour is, however, greater for Conference on QR.708-36 than for the same variety on several other QR.708 selections.

Trial 14

Closely-planted Conference trees in Trial 14 have made least initial growth on the HRI-EM quince selection C.132 and most growth on the *Pyrus* selection QR.708-2 (Table 18).

Yields in the third and fourth years following planting have been highest on QC and poorest on the *Pyrus* selection. Further years will be needed if meaningful results are to be gleaned from this trial.

Trial 15

This trial which is conducted in collaboration with researchers at Randwijk in the Netherlands, is currently too immature to provide meaningful results. The preliminary records of growth and flowering in the first two years following planting are shown in Table 19.

Table 17. Vigour and yields of Conference pear trees planted in spring 1996 on *Pyrus* rootstock selections

Clone	Method of propagation	Total shoot growth/tree (m) 1997-1999	Trunk girth (cm) 2000	Total yields/tree (kg)	
				1999	2000
QR.708-36	Conventional	46.7	16.7	6.0	5.2
QR.708-2	Conventional	41.7	14.9	1.8	2.0
QR.708-2	Microprop.	20.1	11.0	0.9	0.1
QR.708-13	Conventional	22.9	12.4	1.9	1.3
QR.708-13	Microprop.	34.3	14.4	2.7	1.2
QR.708-23	Conventional	11.2	11.8	1.5	2.3

Table 18. Tree size and cropping of Conference planted at close spacings on three different rootstocks in spring 1997

Rootstock	Total shoot length (m) 1997-2000	Trunk girth (cm) 2000	Total yield (kg)		Yield Class I (> 65 mm)	
			1999	2000	1999	2000
QC	21.0	10.6	2.7	2.0	0.4	0.9
C.132	18.0	10.1	1.3	0.8	0.5	0.5
QR.708-2	29.9	12.3	0.6	0.6	0.1	0.2

Table 19. Initial tree vigour and flowering of Comice and Conference trees planted in spring 1999 as 2-yr-old trees on three quince rootstock clones

Scion	Rootstock	Ht. of budding (cm)	Total shoot growth (m) 1999-2000	Trunk girth (cm) 2000	Floral bud numbers/tree 2001
Conference	QC	10	6.0	87.2	30
		25	7.3	8.0	44
	BP.30	10	6.8	8.7	45
		25	6.7	8.3	38
	C.132	10	6.0	7.6	22
		25	5.7	7.1	19
Comice	QC	10	11.6	8.1	13
		25	11.7	8.5	20
	BP.30	10	11.3	9.3	20
		25	9.3	8.7	18
	C.132	10	9.8	8.6	17
		25	8.9	8.0	11

Trials 16-19

Only limited records have to date been taken at the four grower sites evaluating QR.193-16 quince rootstock. The trees are now beginning to crop and slightly more detailed evaluation will be required in the future. On a site near Faversham in Kent, Conference on QR.193-16 are currently smaller trees than Conference on QC. Similar differences in tree size are also noted on a site near Canterbury and a site in Suffolk, where QR.193-16 and QC are compared for Conference and Concorde. No tree size records are currently available for the site in the West Midlands.

5 Grower Summary

The aims of the project have been to

- Evaluate in UK environmental conditions promising advanced selections or released apple and pear rootstocks obtained from breeding and selection programmes operating overseas

- Trial and develop promising apple and pear rootstock selections produced as part of the HRI breeding programme and initially screened in trials funded by the Apple and Pear Breeding Club

Since the beginning of the project (originally funded by the East Malling Trust for Horticultural Research), 19 trials of apple and pear rootstocks have been completed or are still in progress.

Brief notes on each of the rootstocks tested are presented below:

5.1. Apple rootstocks

5.1.1. Sub-clones of the apple rootstock M.9

Burgmer sub clones 719, 751 or 984. Origin Germany: In the East Malling trials these sub-clones usually induced slightly increased vigour compared with EMLA-M.9. It is important to ensure that a virus-free source is guaranteed, if choosing trees on these sub-clones.

Nicolai (K) 29. Origin Belgium: A sub-clone of M.9 selected in Belgium, which induces slightly greater scion vigour than EMLA-M.9. It is similar to the EMLA sub-clone in its effects on yield precocity and efficiency. A suitable choice of M.9 sub-clone where slightly increased vigour is needed in comparison with EMLA-M.9, such as on soils of reduced fertility or with scions of low inherent vigour.

Pajam 1. Origin France: This French virus-free clonal selection of M.9 is very slightly more dwarfing than the EMLA selection of M.9 (5%-10%). Yield precocity and yield efficiency are similar on Pajam 1 and EMLA M.9. Pajam may be a better choice than EMLA-M.9 where slightly reduced vigour is desired, as with certain triploid varieties.

Pajam 2 Origin France: Another French selection of M.9, which is very similar in performance to EMLA-M.9. It would appear to offer no advantages or disadvantages to apple producers in terms of tree vigour and cropping when compared with the EMLA sub-clone.

T.337 Origin Holland: The most popular Dutch sub-clone of M.9, which induces vigour similar or occasionally slightly less than EMLA-M.9. As with most other M.9 sub-clones it induces similar yield precocity and yield efficiency.

None of the other sub-clones of M.9 tested have been made available commercially by nurseries in Europe.

5.1.2 Apple rootstocks obtained from breeding programmes abroad – Completed UK trials

Bemali Origin Sweden: Where no supplementary irrigation was given, the trees on Bemali were of similar size to trees on M.9. However, with irrigation the trees were larger than those on M.26. Yield efficiency (yields in relation to tree size) on Bemali was good for irrigated trees and average/good for trees without irrigation. The percentage of Class 1 (>65mm diameter fruits) was, however quite poor on this rootstock.

Bud (B).9 Origin Russia: Vigour of trees on B.9 in the East Malling trial was similar to vigour on M.9 and Mark. When grown on deeper more fertile soils in other parts of the world, vigour is often closer to that on M.26. Yield efficiency in most trials is slightly inferior to that achieved on M.9. Has value as a cold tolerant rootstock or interstock in areas experiencing very severe winter temperatures. Recent observations in the USA indicate that trees on B.9 suffer less severely from fire blight attacks than trees on M.9 and most other rootstocks tested. Resistant to winter cold injury

Bud 146 Origin Russia: Trees on B.146 were very weak and performed poorly in the East Malling trial. On better soils and with irrigation Dutch results show B.146 to be of similar vigour to M.27. Yield efficiency is very good on this rootstock although fruit size may be reduced. Resistant to winter cold injury

Mark Origin USA: Vigour of Cox on Mark planted in the East Malling trial was very similar to vigour on M.9. However, the rootstock is very sensitive to drought conditions and on hot dry soils very small poor quality trees are produced. In contrast, on deep fertile soils with irrigation tree vigour is more similar to that on M.26. Although there are some reports of increased yield efficiency on Mark, this effect is not consistent from site to site. Mark invariably produces a large swelling on the trunk, either just above aor just below the soil surface. The causes and implications of this anomaly have never been fully researched.

J-TE-E Origin Czech Republic: The Cox trees on the Czech rootstock J-TE-E were smaller than trees on M.9 and when not irrigated were only slightly larger than trees on M.27. However, the trees were a little larger when irrigated. Yield efficiency (yields in relation to tree size) on J-TE-E was very good and equal to M.9. The percentage of Class 1 (>65 mm diameter fruits) was also very good and better than that on M.9. This Czech stock warrants more extensive testing.

J-TE-F Origin Czech Republic: Trees on J-TE-F were intermediate in size between trees on M.27 and M.9.This stock also responded quite positively to trickle irrigation. Yield efficiency (yields in relation to tree size) on J-TE-F was very good and slightly better than for M.9 where no supplementary irrigation was applied. The percentage of Class 1 (>65 mm diameter fruits) was also very good and better than that on M.9. This Czech stock warrants more extensive testing.

J-TE-H Origin Czech Republic: Trees on this rootstock were slightly larger than those on M.26 but of less vigour than trees on MM.106. Yield efficiency (yields in relation to tree size) on J-TE-H was poorer than on M.9 and more similar to the efficiencies shown by M.26 and MM.106. The percentage of Class 1 (>65 mm diameter fruits) was also very good for irrigated trees but relatively poor where no irrigation was applied.

Jork 9 Origin Germany: Trees on Jork 9 were either of M.26 size or larger. Unusually, the largest trees were ones receiving no irrigation; this effect is not understood. Yield efficiency (yields in relation to tree size) on Jork 9 was very good on the irrigated trees but poorer on trees not irrigated. The percentage of Class 1 (>65 mm diameter fruits) was, however, poor for trees on this rootstock. This German stock warrants more extensive testing in organic systems where its apparent drought tolerance may prove useful.

P1 Origin Poland: P1 produced trees more vigorous than trees on M.26 but of less vigour than those on MM.106. Yield efficiency (yields in relation to tree size) on P1 was only average and similar to that on MM.106. The percentage of Class 1 (>65 mm diameter fruits) was relatively poor and significantly worse than on M.26. Resistant to winter cold injury

P.2 Origin Poland: In the East Malling trial vigour of Cox on P.2 was intermediate between vigour on M.27 and M.9. However, on sites in Holland and with trickle irrigation tree vigour on this rootstock is likely to be much closer to that of M.9
Trees should be planted with the rootstock union close to the soil surface if burrknotting and suckering are to be minimised. Resistant to winter cold injury

P.16 Origin Poland: Vigour of trees on P.16 is similar to that on M.9. The stock, which has similar sensitivity to winter cold damage to M.9 (cf. Other Polish stocks), induces excellent yield precocity and yield efficiency. Trees should be planted with their unions as close as possible to the soil surface to reduce the tendency to burr knotting and suckering. The stock is quite sensitive to drought.

P.18 Origin Poland: A very invigorating rootstock which has no advantages and several disadvantages (e.g. poor induction of yield precocity) compared with MM.111. Resistant to winter cold injury

P.60 Origin Poland: Trees on P.60 were of similar size to M.26. Yield efficiency on P.60 was slightly better than on M.26. The percentage of Class 1 (>65 mm diameter fruits) was similar on P.60 and M.26 for irrigated trees but was poorer on P.60 where trees received no irrigation. Resistant to winter cold injury

P.22 Origin Poland: Trees on this stock planted in the un-irrigated East Malling trial were stunted and grew more poorly than trees on M.27. However, in some trials abroad on very deep soils with trickle irrigation provided, vigour on this stock is intermediate between M.27 and M.9. Fruit size was small on this stock at East Malling and similar effects have been noted in the USA. Trees should be planted with the rootstock union close to the soil surface if burrknotting and suckering are to be minimised. Clones of P.22, differing slightly in their vigour and rootstock performance, are now available in mainland Europe. Irrigation and good soil depth and fertility are essential if this stock is chosen. Resistant to winter cold injury

5.1.3 Apple rootstocks obtained from breeding programmes abroad – trials still in existence.

The preliminary results indicate the following

Geneva 1 Origin USA: To date, this rootstock has produced a tree similar in size to trees on M.9. Compared with other stocks in this trial it has induced good yield efficiency. Grade outs have been poor on the young trees in this trial and Geneva 11 has been average in this respect.

Geneva 30 Origin USA: The trees on Geneva 30 are similar in size to the trees on MM.106 but with lower cumulative yields and yield efficiencies. The proportion of Class 1 fruits produced on these trees is, to date only average in comparison with the other rootstocks in the trial.

Geneva 179 Origin USA: This stock is producing trees which currently are similar in size to trees on M.9. It has induced good yield efficiency and, in comparison with the other rootstocks, a good percentage grade out.

Geneva 202 Origin USA: Trees on G.202 are similar or slightly more vigorous than trees on M.9 currently. It has induced the best yield efficiency in this trial and average percentage grade outs of large, quality fruits.

Geneva 210 Origin USA: This rootstock has produced trees slightly larger in size to those on M.9. However, yield efficiency and fruit grade outs have been poor on this selection.

Geneva 730 Origin USA: This rootstock is the most dwarfing of the Geneva series compared in this trial; the trees are currently smaller than those on M.9. However, yield efficiency is poor to date and fruit grade out only average.

Geneva 902 Origin USA: This also produces trees slightly smaller than those on M.9. Yield efficiency has been very good and fruit grade out average.

Vineland Series Origin Canada: The trial is too young to yield any meaningful information currently.

5.1.4 Apple rootstocks selected as part of the Apple and Pear Breeding Club and now being multiplied for further UK testing

The following clones have been selected in screening trials for their induction of appropriate vigour, good yield efficiency, good fruit size in the scion and/or resistance to damaging pests and diseases (woolly apple aphid and collar rot).

Rootstocks with similar vigour to M.27:
AR.69-7, AR.628-2, AR.672-1, AR.682-6

Rootstocks with vigour intermediate between M.27 and M.9
AR360-19, AR.486-1, AR.669-1

Rootstocks with similar vigour to M.9
AR.680-2, AR295-6, AR.120-242

Rootstocks with vigour similar to M.26
AR.801-11

Rootstocks with vigour similar to MM.106
AR.86-1-25, AR.86-1-20, AR.10-3-5

Propagation tests have been conducted on most of these selections under a project previously funded by the EMTHR. The next objective, the raising of sufficient trees for grower trials has been hampered by factors outside the control of the project supervisor. Unfortunately, rootstocks sent to commercial nurseries in the UK for bulking up more than 5 years ago were lost and only recently have the first few trees for further testing of these stocks been raised. It is hoped to raise trees on some of these promising clones for planting in grower trials in winter 2002/2003.

One of the most promising clones is AR.86.1.25, which has similar effects on apple scion vigour and cropping to MM.106, but which is strongly resistant to collar rot. This attribute has prompted the New Zealand licensees of the Apple and Pear Breeding Club to push for its release in the Southern Hemisphere. Once sufficient rootstocks can be raised in Europe, it will be released under the name M.116.

5.2 Pear Rootstocks:

5.2.1 Pear rootstocks produced in breeding programmes abroad

None of the trials are yet completed and the following notes on several of the clones under test should be considered as preliminary comments only:

Pyrodwarf Origin Germany: This dwarfing selection of *Pyrus* showed great promise in trials at its place of origin at Geisenheim in Germany. Trees were reported to be dwarfed and to crop precociously and abundantly. The stock was said to be more graft compatible and more tolerant of poor soil and climatic conditions than quince rootstocks. The trials planted at East Malling are too young to glean meaningful conclusions. Several more years will be needed to achieve this.

BP1 Origin South Africa: This *Pyrus* selection, which was raised in South Africa, is reported to be semi-dwarfing in field trials conducted in Holland. However, in trials conducted at HRI-East Malling and Italy BP1 has proved very sensitive to the phytoplasma Pear Decline. For this reason this rootstock cannot be recommended.

BP30 Origin Sweden: The trial containing this dwarfing *Pyrus* selection from Sweden, is currently too immature to have provided any meaningful results.

Brossier series Origin France: Although some of this series of *Pyrus* rootstocks show promise in terms of their dwarfing effects on tree vigour and induction of cropping, they are extremely difficult to propagate and are unlikely to gain commercial acceptance for this reason. Rigorous attempts to solve this problem using micropropagation techniques (independent project on behalf of a commercial sponsor) proved unsuccessful.

5.2.2. Pear rootstocks produced at HRI-East Malling as part of the Apple and pear Breeding Club agreement

QR.193-16. In most trials, this quince clone produces pear trees which are intermediate in vigour between trees on QC and QA The main merit of QR.193-16 is its effect in increasing fruit size in the scions worked upon it. This effect has been consistent in trials conducted in the UK, France, Spain and Italy. Its main drawback is that cropping begins more slowly following planting than on QC. It is easy to propagate from cuttings. QR.193-16 has been selected for release and will be distributed as EM.H.

C.132. This quince clone, which was selected from seedlings raised many years ago at East Malling, has proved slightly more dwarfing than QC in trials conducted in the Netherlands and the UK. It could have advantages for high density pear production. It is currently undergoing more extensive trialling.

QR.708-36. This clone of *Pyrus communis* was selected at East Malling from a cross made between the pear variety Old Home and the semi-dwarfing *Pyrus* rootstock BP1 (see above). Trees on QR.708-36 are intermediate in vigour and crop precociously and abundantly. In contrast to most other *Pyrus* rootstocks this clone is relatively easy to propagate from semi-hardwood cuttings. This selection is currently on trial in the UK, France and Italy.

Other selections from the QR.708 Series: several of these *Pyrus* clones show initial promise and warrant more extensive testing.

6 Benefits to the Industry

The trials supported by this programme of work provide several benefits to the apple and pear industry:

- The UK trials of rootstocks selected and released from breeding programmes abroad enable growers to gain an objective insight into the advantages and disadvantages of using these rootstocks under UK conditions.
- The trials facilitate the identification of new rootstocks which may provide the UK grower with real benefits, in terms of tree vigour control, induction of cropping, yield abundance, fruit quality and resistance to soil-borne pests and diseases.