Project Title:	Evaluation and development of new rootstocks for apples and pears in conventional management and for apples under organic conditions.
Project Number:	TF134 & TF141
Report:	Report Year 2 TF 134 & Year 1 TF141, August 2004
Previous reports:	TF 134 Year 1 annual report, 31 March 2003
Key Worker:	Mr David Johnson, East Malling Research
Location of Project:	East Malling Research Kent ME19 6BJ Tel: 01732 843833 Fax: 01732 849067
Date Project commenced:	1 April 2002
Date completion due:	31 March 2006
Keywords:	apple, pear, rootstock, Queen Cox, Mondial Gala, Comice, Conference, M9, MM106, M116, EMC, EMH, Pajam 2, Geneva rootstocks, Vineland rootstocks

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

EAST MALLING RESEARCH

Principal Scientists and authors of report:

D S Johnson (Post-harvest Physiologist and project leader)
Ms J E Spencer (Agronomist)

Authentication

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

.....D S Johnson
Signature

Date .....

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Grower Summary

Headline

- In Queen Cox trials at EMR a number rootstocks from the Geneva New York breeding programme have performed better than M9 and are worthy of further evaluation by UK apple growers
- EMH has continued to perform well as a rootstock for Concorde but poor precocity when used for Conference favours the continued use of EMC for this cultivar.

Background

The traditional rootstocks used for apple and pear production in the UK have served growers well over the last 40 years. M.9 and M.26 have induced the required vigour control and have also induced good precocity of flowering/fruiting and acceptable yield abundance in scions worked upon them. However, yields of commodity varieties, such as Gala, are very much higher in parts of southern Europe making costs of production there much cheaper. New dwarfing rootstocks, which induce increased yield, will be required if production of these varieties in the UK is to remain viable. In addition, the trend towards reduced chemical use for fumigation will bring with it a requirement for dwarfing rootstocks with strong resistance to replant disease (SARD). Reduction in herbicide use and water shortages in areas such as Kent will also increase the need for dwarfing rootstocks, which have improved drought tolerance compared with M.9 or M.27.

Where more invigorating trees have been needed, as in cider/juice production or on sub-optimal soils, rootstocks such as MM106 or MM.111 have performed very adequately in the past. However, the winter of 2000/2001 showed how vulnerable trees on MM.106 are to root asphyxiation and the associated sensitivity to collar/crown rots (*Phytophthora sp.*). New semi-dwarfing rootstocks are needed, which show improved tolerance to wet soils and collar/crown rots.

Most pear trees in the UK are grown on either Quince A or Quince C rootstocks. Two of the main problems concerning use of the dwarfing Quince C or Adams quince stocks for Conference are sub-optimal fruit size in some situations and inadequate vigour control to tailor trees to very high-density systems. Use of growth regulators to supplement growth control (e.g. CCC) is no longer permissible.

New quince rootstocks are needed which induce improved fruit size and which are more dwarfing and induce precocious cropping, making them more suitable for high density planting systems.

Although Comice shows very good graft compatibility with quince, the compatibility of Conference is sometimes slightly suspect. Quince stocks are also sensitive to both winter cold injury and high pH soils and are also poorly anchored compared with Pyrus rootstocks. Most new varieties of pears produced world wide show incompatibility with quince stocks and should UK growers wish to plant any of these growers will need to use compatible interstocks, if improved compatible rootstocks

cannot be selected. Growers in the USA use Pyrus seedling or clonal stocks for pears and these show good graft compatibility with all pear varieties. However, most traditional Pyrus rootstocks are very invigorating and the clonal selections are difficult to propagate. Recent breeding and selection work carried out in Europe has produced several clones of *Pyrus communis* which are dwarfing and many pear producing countries are now beginning to test these as alternatives to use of quince rootstocks.

Expected deliverables

The main purpose of the project is to acquire, evaluate and develop in UK growing conditions new apple and pear rootstocks produced by breeding programmes both at HRI and abroad.

The specific objectives are as follows:

- To select and develop dwarfing apple rootstocks which induce increased yield productivity in comparison with M.9 or M.26
- To select and develop dwarfing rootstocks for apple which exhibit improved resistance to drought, (weed competition) replant disease and soil borne diseases (e.g. collar/crown rot)
- To select and develop semi-dwarfing rootstocks which show improved resistance to soil asphyxiation and collar/crown rots than MM.106
- To select and develop quince rootstocks, which induce improved fruit size
- To select and develop quince rootstocks more dwarfing than Quince C
- To select dwarfing Pyrus rootstocks, which are easy to propagate, and induce good yield precocity/productivity.
- To select rootstocks for both apple and pear, which are suitable for organic systems of production.

Summary of the project and main conclusion

<u>Apple rootstock trials planted at HRI-East Malling</u>

Currently two trials of apple rootstocks raised by breeders based outside of the UK are planted.

In the older (Queen Cox) trial planted in spring 1995 new rootstocks from the Geneva New York breeding programme are being compared with M9 and MM106. These rootstocks, some of which are now becoming available commercially in Europe, were bred to provide improved resistance to winter cold injury, fireblight, woolly apple aphid, crown rot and tomato ringspot virus. Several rootstocks from this programme are showing initial promise in trials conducted in New Zealand and the USA. With vigour closer to M26 than to M.9 one or more of these rootstocks may have potential on sites where there is significant weed/grass competition for water and nutrients.

G.11, G.902, G.730 and G.202 performed particularly well in the trial at EMR. Although of similar vigour to M.9, G.11 and G.202 had a higher cropping efficiency and G.202 had a higher cumulative yield. G.902 and G.730 produced smaller trees than M.9 but yield efficiency was similar (G.902) or greater (G.730). Five of the

Geneva rootstocks have been released for commercial propagation and these include three of those in trial at East Malling (G.11, G.30 and G.202).

The younger (Mondial Gala) trial planted in spring 2000 (Plot DM172) compares three of the rootstocks raised at the Vineland Research Station in Canada with the French Pajam 2 rootstock. These rootstocks are equivalent to M.9-M.26 in vigour but possibly have better cold and drought resistance than M.9. The Vineland series of rootstocks were bred to provide improved cold tolerance, but have also performed well in less severe conditions on some USA sites.

At the time of planting in March 2000 the tree quality of these bench grafts was very poor in comparison with the trees on Pajam 2. The growth of the Vineland rootstocks was poor in the first year but total shoot growth exceeded that of Pajam 2 in 2002. Currently the number of dead or diseased trees for rootstocks V.1, V.3, V.4 and Pajam 2 is 1, 5, 3 and 1 out of 6 respectively. Clearly it is not possible to assess the performance of trees on V.3 rootstock and results for V.4 are based on only 50% of the trees originally planted. In view of the tree health problem it is likely that the trial will be terminated in the coming winter.V.4 was more vigorous than Pajam 2 with a greater number and length of shoots. V.1 was similar in these respects to Pajam 2. The yield efficiency of both Vineland stocks was similar but tended to be lower than for Pajam 2.

A new trial was planted on 8 May 2003 (Plot EE 195) to evaluate new rootstocks from the breeding program at East Malling. A similar trial was planted in the organic area at East Malling (Plot GE 182) in order to evaluate the performance of new rootstock selections under conditions that are generally more restrictive in terms of moisture and nutrient availability (Project TF141). Trees of Queen Cox on 3 new rootstock selections (AR 486-1, AR 295-6 and AR120-242) are being compared with M.9 and on Bramley's Seedling 4 new rootstock selections (AR 628-2, AR 69-7, AR 360-19 and AR 801-11) are being compared with M.27. The trees have yet to establish after being planted late and being subject to an exceptionally hot, dry summer. It was interesting to note however that Bramley trees on M27 under conventional management achieved higher shoot numbers and lengths than under organic management.

Pear rootstock trials planted at HRI-East Malling

Three trials of quince and *Pyrus* rootstocks planted at East Malling continue to be evaluated. Two of these trials include C.132, a quince rootstock from the HRI breeding programme, which is slightly more dwarfing than Quince C and possibly more winter hardy. In one of these trials C.132 is compared with Quince C (EMC) and a promising Swedish *Pyrus* selection (BP30) and, in the other, it is compared with EMC and a dwarfing *Pyrus* selection from the HRI programme, QR 708/2. In the third trial a new dwarfing *Pyrus* selected at Geisenheim, in Germany, named 'Pyrodwarf' is being evaluated along with *Pyrus* scion varieties (Gieser Wildeman, Delbuena and Dolacomi) used as rootstocks. The performance of EMH, EMA and EMC rootstocks on Concorde and Conference has continued at one commercial orchard in East Kent.

Results with C132 in the two trials at East Malling have been contradictory particularly as regards the vigour of the rootstock in comparison with EMC. In the younger trial there was no greater dwarfing effect of C132 on either Conference or Comice and, though cumulative yield of class 1 fruit above 65mm was higher than for EMC, yield efficiency was lower. In the older trial Conference on C132 was less vigorous than EMC and though cumulative yield was lower the yield efficiencies of C132 and EMC were the same. Tree density may be a factor influencing the comparative vigour of Conference on the different stocks. In the older trial the trees were more densely planted than in the younger trial.

BP30 has proved more vigorous than EMC but yield in 2003 and yield efficiency was lower. Although for Conference BP30 resulted in a larger tree volume compared with EMC, on Comice tree volume was less on BP30.

QR708/2 continues to be more vigorous than EMC but has a lower cumulative yield and yield efficiency and appears to be incompatible with Conference with the result that 50% of the trees have died.

In comparison with EMC, 'Pyrodwarf' and pear scion varieties used as rootstocks, were more vigorous but less yield-efficient and reduced accumulated yields of Comice although only Dolacomi reduced accumulated yields of Conference pears. High mortality rates have occurred on Conference and Comice trees on the quince rootstock 'Sobu'.

In a commercial orchard in East Kent, Concorde trees on EMH continue to be less vigorous than on EMA. Surprisingly, Conference trees on EMH continue to be smaller than those on EMC. Yields (2003 and accumulated) and mean fruit weight of Concorde on EMA and EMH were similar although EMH tended to be more yield-efficient. Yields of Conference were lower (by 45%) on EMH compared with EMC and mean fruit weights were similar.

Financial benefits

There are major financial implications of identifying rootstocks for apples and pears with improved agronomic performance and that satisfy consumer requirements in terms of fruit size and quality.

Action points

- On the evidence of 8 years of results from a Queen Cox trial at EMR growers should consider planting trees raised on rootstocks from the Geneva New York breeding programme as possible alternatives to M9. G.202 performed particularly well being of similar vigour to M9 but with a higher cropping efficiency and a higher cumulative yield. It is advised that UK growers should examine the portfolio of the five Geneva rootstocks that have been released for commercial propagation three of which (G.11, G.30 and G.202) have been trialled at EMR.
- Rootstocks from the Vineland Research Station in Canada offer no advantages to the UK apple grower when compared with Pajam 2, a French selection of M9.

- In a commercial orchard trial EMH has continued to perform well as a rootstock for Concorde providing similar yields as EMA but with reduced tree size and greater yield efficiency. Growers considering further plantings of Concorde are advised to consider the use of EMH as the most suitable rootstock.
- The traditional EMC rootstock may be preferred to EMH for Conference pears in view of the poor precocity of EMH.

Science Section

Introduction

For the 6 years leading up to 31 March 2001 the selection, development and evaluation of new apple and pear rootstocks in the UK was funded by the EM Trust for Horticultural Research with additional funding from APRC in 2000-01. A report on the work carried out during that 6-year period was prepared by Tony Webster and colleagues and submitted to APRC (SP123) and the EM Trust in 2001. In 2001-02 the evaluation and development of new rootstocks for apples and pears was continued in a 1-year APRC project (SP134) and a report on the work carried out from April 2001 until March 2002 was submitted to APRC in April 2002. Subsequently APRC Council agreed to continue project SP134 for a further 3 years (March 2005). This is a report on the work carried out from April 2003 until March 2004. Recent successes of the trialling programme include the release in 2001 of a new dwarfing quince rootstock for pears (EMH) and a new apple rootstock resistant to crown / collar rot (M.116).

Apple rootstock trials planted at HRI-East Malling

Currently two trials of apple rootstocks raised by breeders based outside of the UK are planted.

In the older (Queen Cox) trial planted in spring 1995 (Plot DM167) new rootstocks from the Geneva New York breeding programme are being compared with M9 and MM106. 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. Several rootstocks from this programme are showing initial promise in trials conducted in New Zealand and the USA. With vigour closer to M26 than to M.9 one or more of these rootstocks may have potential on sites where there is significant weed/grass competition for water and nutrients.

The younger (Mondial Gala) trial planted in spring 2000 (Plot DM172) compares three of the rootstocks raised at the Vineland Research Station in Canada with the French Pajam 2 rootstock. These rootstocks are M.9-M.26 in vigour but possibly have better cold and drought resistance than M.9. The Vineland series of rootstocks were bred to provide improved cold tolerance, but have also performed well in less severe conditions on some USA sites.

A new trial was planted on 8 May 2003 (Plot EE 195) to evaluate new rootstocks from the breeding program at East Malling. On Queen Cox 3 new rootstock selections (AR 486-1, AR 295-6 and AR 120-242) are being compared with M.9 and on Bramley's Seedling 4 new rootstock selections (AR 628-2, AR 69-7, AR 360-19 and AR 801-11) are being compared with M.27.

Pear rootstock trials planted at HRI-East Malling

Three trials of quince and *Pyrus* rootstocks planted at East Malling continue to be evaluated. Two of these trials include C.132, a quince rootstock from the HRI breeding programme, which is slightly more dwarfing than Quince C and possibly more winter hardy. In one of these trials (Plot PR 184) C.132 is compared with Quince C (EMC) and a promising Swedish *Pyrus* selection (BP30) and, in the other (Plot PR173), it is compared with EMC and a dwarfing *Pyrus* selection from the HRI programme, QR 708/2. In the third trial (Plot PR187) a new dwarfing *Pyrus* selected at Geisenheim, in Germany, named 'Pyrodwarf' is being evaluated along with the quince rootstock 'Sobu', and pear scion varieties as potential rootstocks.

The performance of EMH, EMA and EMC rootstocks on Concorde and Conference has continued at one commercial orchard in East Kent.

Materials and Methods

In all of the East Malling trials, the tree rows were maintained weed free using conventional herbicides and the alleys between the rows were grassed down and maintained by frequent mowing. No supplementary irrigation was supplied to the trees. Minimal pruning was undertaken in the first few years following planting; the trees were, however, headed when necessary to encourage the production of lateral branches, but no branch tipping was undertaken. Where appropriate, very upright branches were tied down towards the horizontal and a modified form of 'long pruning' employed. No chemical growth regulators or root pruning techniques have been used to supplement growth control in any of the trials reported on.

Measurements were taken annually of trunk girth 25cm above ground level and of shoot length and the numbers of shoots were counted. Total yields and yields of class 1 fruit above 65mm diameter were measured and cumulative yields and yield efficiencies were calculated. Notes on tree health and graft compatibility were also made.

Results and Discussion

Performance of Queen Cox on Geneva rootstocks (Tables 1 and 2)

Sufficient data has been gathered since 1995 to make an objective assessment of the performance of Queen Cox on the Cornell-Geneva rootstocks. Vigour of the rootstocks can be assessed by the annual girth measurement and by the estimates of tree volume.

Geneva 11 (G.11) was not significantly less vigorous than M.9 as evidenced by girth measurements although tree volume in 2003 was almost significantly lower. Yields in 2003 and accumulated yield (total and % Class 1) were similar to M.9 but yield efficiency was higher.

Geneva 30 (G.30) was similar to MM.106 with regard to growth and cropping although in 2003 the yield of class 1 fruit above 65 mm was lower.

Geneva 902 (G.902) has produced trees less vigorous than M.9 but with similar yields (2003 and accumulated) and similar yield efficiency.

Geneva 730 (G.730) has produced trees less vigorous than M.9. Although accumulated yield was less than for M.9 yield efficiency was higher.

Geneva 202 (G.202) tended to be of similar vigour (girth) than M9 although tree volume was almost significantly lower in 2003. Cumulative yield (total and % Class 1) and yield efficiency were greater than for M.9.

Geneva 210 (G.210) produced a similar tree volume to M.9 although tree girth tended to be greater. Although in 2003 yields of class 1 fruit above 65mm were higher than for M.9, cumulative yield and yield efficiency were similar to M.9.

Geneva 179 (G.179) has produced trees that have performed similarly to M.9.

G.11, G.902, G.730 and G.202 performed particularly well in this trial. Although of similar vigour to M.9, G.11 and G.202 had a higher cropping efficiency and G.202 had a higher cumulative yield. G.902 and G.730 produced smaller trees than M.9 but yield efficiency was similar (G.902) or greater (G.730).

Five of the Geneva rootstocks have been released for commercial propagation and these include 3 of those in trial at East Malling (G.11, G.30 and G.202). Information on the performance of Cornell-Geneva apple rootstocks in New York on-farm trials has recently been published (Robinson et. al., 2003). In the US G.11 is considered a good replacement for M.26 and has fireblight tolerance similar to M7 and good resistance to crown rot. G.202 is slightly more vigorous than M.26 and is immune to fireblight and has good resistance to *Phytophthora*, apple replant disease and woolly apple aphid. New Zealand results also confirm the potential of G.202 as a highly productive semi-dwarfing rootstock well adapted for use on replant soils (Tustin et. al., 2003).

Table 1. Size and yields (2003 crop) of Queen Cox trees planted on Cornell-Geneva (USA) rootstocks in 1995. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Trunk girth 2003 (cm / tree)	Tree volume 2003 (m^3)	Yield 2003 (kg / tree)	
			Total	Class 1 >65 mm
G.11	24.10	26.37	22.43	12.57
G.30	30.26	41.31	26.72	14.97
G.902	21.54	17.83	17.18	8.43
G.730	18.33	14.53	16.92	10.25
G.202	24.95	26.82	20.18	11.17
G.210	26.74	31.34	23.38	15.18
G.179	24.80	33.42	18.60	11.20
M.9	25.08	32.55	19.67	11.18
MM.106	31.23	46.58	31.13	19.02
SED (33 df)	1.028	3.523	2.692	1.963
LSD (P=0.05)	2.099	7.194	5.497	4.008
Rootstock effect	***	***	***	***

Table 2. Accumulated yields and yield efficiencies of Queen Cox trees planted on Cornell-Geneva (USA) rootstocks in 1995. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Cumulative yield (kg / tree) 1996-03		Yield efficiency (kg / cm^2)
	Total	Class 1 >65 mm	2003
G.11	95.4	55.6	2.069
G.30	129.2	73.5	1.739
G.902	72.1	41.0	1.993
G.730	60.4	38.5	2.211
G.202	100.1	58.8	2.096
G.210	84.5	51.4	1.461
G.179	84.3	51.7	1.680
M.9	81.0	46.6	1.634
MM.106	149.0	91.3	1.921
SED (33 df)	9.71	6.24	0.2478
LSD (P=0.05)	19.83	12.74	0.5060
Rootstock effect	***	***	n.s.

Performance of Mondial Gala on Vineland rootstocks

As noted previously (see report on SP134 to 31 March 2002) 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. The growth of the Vineland rootstocks was poor in the first year but total shoot growth exceeded that of Pajam 2 in 2002 (see report to March 2003). The number of dead or diseased trees for rootstocks V.1, V.3, V.4 and Pajam 2 is currently 1, 5, 3 and 1 out of 6 respectively. Clearly it is not possible to assess the performance of trees on V.3 rootstock and results for V.4 are based on only 50% of the trees originally planted. In view of the tree health problem it is likely that the trial will be terminated in the coming winter.

V.4 was more vigorous than Pajam 2 with a greater number and length of shoots (Table 3). V.1 was similar in these respects to Pajam 2. The yield efficiency of both Vineland stocks was similar and lower than for Pajam 2 although this effect just failed to reach significance at the 5% level (Table 4).

In current trials in Massachusetts, USA using McIntosh trees on a range of Vineland rootstocks V.4 has proved to the most vigorous and more so than M26 and comparable to M7 (Autio and Krupa, 2002). In our trial on Mondial Gala V.4 was more vigorous than M.9 but had not shown the vigour reported in the US trials. In the latter trials V.3 was the most dwarfing stock and along with V.1 has proved to be most yield-efficient. It is unfortunate that health problems have plagued our evaluation of the Vineland stocks particularly as the results of US trials are favourable and further evaluation in the US is being suggested.

Table 3. Growth in 2003 of Mondial Gala trees on Vineland rootstocks planted in spring 2000. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability). †-no data, 5 of 6 trees planted have died.

Rootstock	Girth (cm / tree)	Total shoot length (dm / tree)	Mean shoot length (dm / tree)	Total shoot number
V.1	10.51	186	2.96	59.6
V.3†				
V.4	13.76	304	3.30	97.2
Pajam 2	10.56	174	2.85	60.1
SED (5 df)	0.9231	37.6	0.316	7.93
LSD (P=0.05)	2.373	96.67		20.39
Rootstock effect	*	*	n.s.	**

Table 4. Cropping in 2003 of Mondial Gala trees on Vineland rootstocks planted in spring 2000. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability). †-no data, 5 of 6 trees planted have died.

Rootstock	Total yield (kg / tree)		Yield Class 1 >65 mm (kg / tree)		Yield efficiency (kg / cm^2)
	2003	Cumulative	2003	Cumulative	2003
V.1	9.0	13.1	8.1	10.4	1.28
V.3†					
V.4	12.8	15.4	5.9	7.1	1.22
Pajam 2	12.8	21.2	10.4	16.3	2.32
SED (5 df)	3.22	5.26	3.87	5.69	0.402
LSD (P=0.05)					
Rootstock effect	n.s.	n.s.	n.s.	n.s.	n.s.

Performance of Queen Cox on new East Malling rootstock selections

Under conventional management

There were only sufficient grafted 2-year-old trees of AR 295-6 and AR 120-242 to complete 4 and 5 of the 8 blocks respectively. The remaining blocks were completed using budded 1-year-old trees. The analysis of the growth data for 2003 was necessarily restricted to the 4 complete blocks of grafted trees. It is anticipated that as the trees get older any potential differences between the budded and grafted trees will diminish and it will be appropriate to use all 8 replicate trees in the statistical analysis.

In 2003 the girth of AR 120-242 was more than M.9 (Table 5). Cox on AR 295-6 tended to have lower shoot numbers than M.9 trees although the effect just failed to reach significance. The tendency for higher numbers of shoots on control (M.9) trees may reflect the fact that these were produced in the Netherlands whereas the remaining trees were raised in the UK.

Table 5. Growth in 2003 of Queen Cox trees on rootstocks from the East Malling breeding program planted in spring 2003. Data presented for blocks 1-IV only (see text). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Girth (cm / tree)	Total shoot length (dm / tree)	Total shoot number
AR 486-1	5.15	15.2	9.75
AR 295-6	4.75	17.0	5.0
AR 120-242	6.40	18.5	9.25
M9	5.15	17.2	12.25
SED (9 df)	0.298	4.01	2.358
LSD (P=0.05)	0.7808		
Rootstock effect	**	n.s.	n.s.

Under organic management (Project TF141)

There were only sufficient grafted 2-year-old trees of AR 295-6 to complete 4 of the 8 blocks respectively. The remaining blocks were completed using budded 1-year-old trees. In order to compare all rootstocks the analysis of the growth data for 2003 was necessarily restricted to the 4 complete blocks of grafted trees. It is anticipated that as the trees get older any potential differences between the budded and grafted trees will diminish and it will be appropriate to use all 8 replicate trees in the statistical analysis. To compare only AR 486-1, AR 120-242 and M9 the data can be restricted so that the data for all 8 blocks are used.

There were no significant effects of rootstock tree girth or shoot length but numbers of shoots produced by AR 486-1 and AR 295-6 were less than by M9 (Table 6). In the conventionally managed orchard AR 295-6 also produced the least number of shoots although the effect just failed to reach significance. In an analysis of the data excluding AR 295-6 the girth increase by AR 120-242 over M9 was significant and was similar to the effect in the conventional orchard.

Table 6. Growth in 2003 of Queen Cox trees on rootstocks from the East Malling breeding program planted in spring 2003 and managed under organic conditions. Data presented for blocks 1-IV only (see text). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Girth (cm / tree)	Total shoot length (dm / tree)	Total shoot number
AR 486-1	4.98	11.2	7.25
AR 295-6	5.10	16.8	7.75
AR 120-242	5.60	14.5	9.75
M9	4.88	19.0	12.75
SED (9 df)	0.540	3.65	1.860
LSD (P=0.05)			4.873
Rootstock effect	n.s.	n.s.	*

Performance of Bramley's Seedling on new East Malling rootstock selections

Under conventional management

The design of the trial was complicated by insufficient numbers of grafted trees for AR 360-19 and AR 801-11 to complete 8 blocks as planned. There were sufficient trees for 5 blocks of these rootstocks and 8 blocks of AR 628-2, AR 69-7 and M.27 controls. Additional trees on AR 628-2, AR 69-7 were used to complete the blocks.

The analysis of the growth data for 2003 was necessarily restricted to the 5 complete blocks of grafted trees. In addition the trees with 8 replicates (AR 628-2, AR 69-7 and M.27) were analysed separately.

In 2003 all stocks had a greater girth measurement than M.27 (Table 7). This may reflect the fact that the control trees were one year old and were obtained from a different UK nursery to the 2-year-old trees on the experimental rootstocks. However it is expected that these rootstocks are likely to provide tree sizes in the M.27-M.9 range. It is anticipated that as the trees get older any potential differences due to tree age at planting will diminish.

Table 7. Growth in 2003 of Bramley trees on rootstocks from the East Malling breeding program planted in spring 2003. Data presented for blocks 1-V only (see text). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Girth (cm / tree)	Total shoot length (dm / tree)	Total shoot number
AR 628-2	6.00	5.2	3.6
AR 69-7	5.22	3.6	2.6
AR 360-19	5.64	3.0	2.4
AR 801-11	5.66	5.8	3.6
M27	4.50	4.2	3.4
SED (16 df)	0.248	1.047	0.73
LSD (P=0.05)	0.5264		
Rootstock effect	***	n.s.	n.s.

Under organic management (Project TF141)

The constraints on the design of the orchard under conventional management imposed by lack of sufficient grafted trees (see above) applied also to the orchard planted in the organic area at East Malling.

With the exception of AR 360-19 all stocks had a greater girth measurement in 2003 than M.27 (Table 8). The results were similar to those obtained in the orchard managed conventionally although AR 360-19 also had a greater girth than M27. As stated previously differences in girth measurements may reflect the fact that the control (M27) trees were one year old and were obtained from a different UK nursery to the 2-year-old trees on the experimental rootstocks. However it is expected that these rootstocks are likely to provide tree sizes in the M.27-M.9 range. It is anticipated that as the trees get older any potential differences due to tree age at planting will diminish. Although there were no significant effects of rootstock on the numbers or lengths of shoots it is interesting to note that M27 trees in the organic orchard had much reduced numbers and lengths of shoots compared with those in conventional production.

Table 8. Growth in 2003 of Bramley trees on rootstocks from the East Malling breeding program planted in spring 2003. Data presented for blocks 1-V only (see text). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Girth (cm / tree)	Total shoot length (dm / tree)	Total shoot number
AR 628-2	5.50	3.6	2.2
AR 69-7	5.64	3.2	2.6
AR 360-19	4.58	3.8	3.0
AR 801-11	6.62	6.0	3.8
M27	4.38	1.8	1.8
SED (16 df)	0.350	1.51	1.03
LSD (P=0.05)	0.742		
Rootstock effect	***	n.s.	n.s.

Performance of Comice and Conference on Quince (EMC, C132 and BP30) rootstocks

The trees on PR184 were budded at 10 and 25 cm. Previous work (see final report on SP123) had shown that increasing the height of budding on Comice reduced the vigour of Quince C rootstock. In 2003 trunk girth on Comice was reduced by budding at 25 cm although the effect just failed to reach significance at the 5% level. Bud height did not affect the girth of Conference trees. The higher bud height increased yield efficiency of EMC trees but did not affect trees on BP30 or C132 rootstocks.

Girth data indicated no greater dwarfing effect of C132 on either variety (Table 10). Although cumulative yield of class 1 fruit above 65mm was higher than for EMC yield efficiency was lower (Table 9).

The girths of trees on BP30 rootstocks were greater than those on EMC indicating greater vigour but yield in 2003 and yield efficiency were lower for trees on BP30 rootstocks. Consistent with effects of BP30 on trunk girth the volume of Conference trees in 2003 was greater than on EMC rootstocks. However, on Comice tree volume was less on BP30 rootstocks than on EMC.

Table 9. Cropping in 2003 of Comice and Conference trees on Quince rootstocks planted spring 1999 (Plot PR 184). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Variety	Rootstock	Graft height (cm)	Total yield (kg / tree)		Yield Class 1 >65 mm (kg / tree)	
			2003	cumulative	2003	Cumulative
Comice	EMC	10	6.6	11.76	4.72	9.0
	EMC	25	6.1	13.06	4.11	9.92
	BP30	10	4.15	11.39	3.39	9.72
	BP30	25	3.80	11.01	3.53	9.65
	C132	10	6.59	13.61	5.62	12.0
	C132	25	5.06	11.65	4.88	10.28
Conference	EMC	10	3.14	9.66	0.06	0.75
	EMC	25	3.98	11.58	0.02	0.63
	BP30	10	3.26	9.74	0.05	1.37
	BP30	25	3.15	9.11	0.01	1.51
	C132	10	4.61	9.19	0.02	1.07
	C132	25	4.91	10.68	0.38	3.77
Overall effect	EMC		4.95	11.51	2.23	5.08
	BP30		3.59	10.31	1.74	5.56
	C132		5.29	11.28	2.73	6.78
SED(95 df)			0.515	0.862	0.439	0.688
LSD (P=0.05)			1.030			1.376
Rootstock effect			**	n.s.	n.s.	*

Table 10. Growth in 2003 of Comice and Conference trees on Quince rootstocks planted spring 1999 (Plot PR 184). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Variety	Rootstock	Graft height (cm)	Girth (cm / tree)	Tree Volume (m^3)	Yield efficiency (kg / cm^2)
Comice	EMC	10	15.20	8.58	0.588
	EMC	25	14.36	9.09	0.796
	BP30	10	15.88	7.41	0.566
	BP30	25	15.66	7.58	0.564
	C132	10	16.19	8.96	0.650
	C132	25	14.40	9.31	0.706
Conference	EMC	10	11.35	4.09	0.919
	EMC	25	11.50	4.64	1.078
	BP30	10	11.91	5.05	0.870
	BP30	25	12.68	6.55	0.722
	C132	10	12.30	5.06	0.747
	C132	25	11.76	5.48	0.915
Overall effect	EMC		13.10	6.60	0.845
	BP30		14.03	6.65	0.680
	C132		13.66	7.20	0.754
SED (95 df)			0.381	0.456	0.0482
LSD (P=0.05)			0.762	1.290	0.0964
Rootstock effect			*	n.s.	**

Performance of Conference on Quince (EMC and C132) and *Pyrus* (QR708/2) rootstocks

QR708/2 continues to be more vigorous than EMC as evidenced by a greater girth and tree volume in 2003 but has a lower cumulative yield and yield efficiency (Tables 9 and 10). As noted in the previous report there appears to be an incompatibility between Conference and QR708/2 with the result that 50% of the trees have died.

Statistical analysis of the data was repeated in order to compare EMC and C132 without the effect of missing data values for QR708/2 in the analysis of variance. Analysis of the restricted data showed that C132 was less vigorous than EMC and although cumulative yield was lower the yield efficiencies of C132 and EMC were the same (Tables 11 and 12).

Table 11. Growth and cropping in 2003 of Conference trees on Quince (EMC and C132) and *Pyrus* (QR708/2) rootstocks planted spring 1997 (Plot PR 173). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Girth 2003 (cm / tree)	Yield 2003 (kg / tree)		Tree Volume 2003 (m^3)
		Total	Class 1 >65 mm	
QR708/2	17.85	5.25	0.02	6.07
C132	12.54	5.70	0.02	2.96
EMC	14.06	7.19	0.02	4.80
SED (13 df)	1.143	0.998	Insufficient data	0.863
LSD (P=0.05)	2.469	-		1.864
Rootstock effect	***	n.s.		**

Table 12. Cumulative yield and yield efficiency of Conference trees on Quince (EMC and C132) and *Pyrus* (QR708/2) rootstocks planted spring 1997 (Plot PR 173). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

Rootstock	Cumulative yield 1999-03 (kg / tree)		Yield efficiency (kg / cm^2)
	Total	Class 1 >65 mm	
QR708/2	18.2	2.09	0.660
C132	18.3	2.80	1.422
EMC	24.6	4.13	1.550
SED (13 df)	2.69	0.977	0.0935
LSD (P=0.05)	5.81	-	0.2020
Rootstock effect	*	n.s.	***

Performance of Conference and Comice on Quince (Sobu and EMC) and *Pyrus* (Pyrodwarf) rootstocks and on pear scion varieties (Gieser Wildeman, Delbuena and Dolacomi) as rootstocks

The trees planted in this trial in the spring of 2000 were 2 years old and well feathered. Although the first significant crop was produced in 2002 the effects of rootstock on cropping can only be assessed after a number of years of sustained yields. There appears to be an incompatibility with Sobu with the result that 30% of Comice and 60% of Conference trees have died. Data for Sobu were excluded from the statistical analysis. Although data for Sobu are presented in Tables 11 the SED's and LSD's provided do not apply to any comparisons between means for Sobu and any other rootstocks.

In comparison with EMC, Pyrodwarf, and pear scions as rootstocks, increased trunk girth and were less yield-efficient and Delbuena and Pyrodwarf increased tree volume (Table 13). In 2003 yields of Conference pears on Pyrodwarf and pear scions as rootstocks were the same as on EMC but on Comice pears, with the exception of Delbuena, they produced lower yields. In comparison with EMC, Pyrodwarf, and pear scions as rootstocks, reduced accumulated yields of Comice but only Dolacomi reduced accumulated yields of Conference pears.

Table 13. Growth (girths) and cropping in 2003 of Conference and Comice trees on Quince (Q) and *Pyrus* (P) rootstocks (including pear scion varieties Gieser Wildeman, Delbuena and Dolacomi as rootstocks) planted spring 2000 (Plot PR 187). (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability). Sobu not included in the statistical analysis due to a large number of dead trees.

Rootstock	Girth (cm / tree)	Tree Volume 2003 (m^3)	Yield 2003 (kg / tree)		Cumulative yield 1999-03 (kg / tree)		Yield efficiency (kg / cm^2)
			Total	Class 1 >65 mm	Total	Class 1 >65 mm	
Conference							
G Wildeman (P)	15.22	5.73	5.82	0.03	7.40	0.28	0.369
Delbuena (P)	15.52	6.11	5.63	0.16	7.89	0.39	0.459
Dolacomi (P)	14.93	5.78	3.83	0.11	5.11	0.21	0.307
Pyrodwarf (P)	17.33	7.06	6.22	0.03	7.65	0.06	0.324
Sobu (Q)	11.80	3.62	4.66	0.06	7.52	1.26	0.677
EMC (Q)	11.98	3.84	4.94	0.00	8.66	0.74	0.741
Comice							
G Wildeman (P)	15.24	6.54	2.11	1.30	2.16	1.32	0.980
Delbuena (P)	18.05	8.21	6.17	3.74	7.15	4.42	0.287
Dolacomi (P)	16.45	6.39	4.18	1.72	4.37	1.85	0.204
Pyrodwarf (P)	18.88	7.56	4.59	2.57	4.97	2.82	0.184
Sobu (Q)	14.49	4.99	7.04	4.19	9.15	5.86	0.536
EMC (Q)	15.74	6.64	7.00	3.15	10.83	6.03	0.586
Overall effect							
G Wildeman (P)	15.23	6.14	3.96	0.67	4.78	0.80	0.233
Delbuena (P)	16.79	7.16	5.90	1.95	7.52	2.40	0.373
Dolacomi (P)	15.69	6.08	4.00	0.92	4.74	1.03	0.255
Pyrodwarf (P)	18.10	7.31	5.40	1.30	6.31	1.44	0.254
Sobu (Q)	13.14	4.31	5.85	2.13	8.34	3.56	0.606
EMC (Q)	13.86	5.24	5.97	1.58	9.74	3.39	0.663
SED (77 df)	0.751	0.715	0.860	0.439	1.120	0.511	0.0625
LSD (P=0.05)							
Rootstock effect	***	*	*	*	***	***	***

Performance of EMH (QR 193-16) in a commercial orchard

The performance of EMH, EMA and EMC rootstocks on Concorde and Conference has continued at one commercial orchard in East Kent. As expected Concorde trees on EMH continue to be less vigorous than on EMA. Surprisingly Conference trees on EMH continue to be smaller than those on EMC (Table 14). As mentioned in the previous report EMH is usually more vigorous than EMC although in hot dry conditions such as in the south of France Comice and Conference trees on EMH were smaller than those on EMC. Trees are just coming into crop in the commercial orchard.

Yields (2003 and accumulated) and mean fruit weight of Concorde on EMA and EMH were similar although EMH tended to be more yield-efficient (Table 15). Higher yields (2003 and accumulated) of Conference were obtained on EMC compared with EMH and mean fruit weights were similar. Previous trials have shown that trees on EMC are more precocious than on EMH but by the fifth leaf yields on EMH are normally equal to EMC. However in this trial planted in spring 1997 the yields of Conference on EMC rootstocks continue to exceed those on EMH.

Table 14. Girth measurements and cropping of Conference and Concorde pears in 2003 on EMA, EMC and EMH rootstocks in a commercial orchard in East Kent. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

	Rootstock	Girth 2003 (cm / tree)	Yield 2003 (kg / tree)	Mean fruit weight (g)	Fruit number / tree 2003
Concorde	EMA	21.52	3.03	212.9	14.5
	EMH	16.29	3.47	219.4	16.8
Conference	EMC	17.30	8.74	164.6	55.8
	EMH	14.90	5.05	179.1	28.6
SED (72 df)		0.542	0.785	8.48	5.27
LSD (P=0.05)		1.084	1.570	16.96	10.54
Rootstock effect		***	***	***	***

Table 15. Cumulative yield and cropping efficiency of Conference and Concorde pears on EMA, EMC and EMH rootstocks in a commercial orchard in East Kent. (SED–Standard Error of the Difference between means, LSD–Least Significant Difference between means, df–degrees of freedom, rootstock effect was either non-significant (n.s.) or significant at the 5(*), 1(**) or 0.1%(***) level of probability).

	Rootstock	Cumulative fruit number / tree 2000-03	Yield efficiency by number (number / cm^2)	Cumulative yield 2000-03 (kg / tree)	Yield efficiency by weight (kg / cm^2)
Concorde	EMA	41.3	1.15	6.37	0.177
	EMH	37.2	1.88	5.86	0.284
Conference	EMC	120.4	4.84	14.66	0.589
	EMH	44.1	2.43	6.64	0.359
SED (72 df)		10.76	0.372	1.462	0.0485
LSD (P=0.05)		21.52	0.9895	2.924	0.1290
Rootstock effect		***	***	***	***

Conclusions

Apple rootstock trials planted at HRI-East Malling

Four of the rootstocks from the Geneva New York breeding programme, namely G.11, G.902, G.730 and G.202, performed particularly well in the trial on Queen Cox. Although of similar vigour to M.9, G.11 and G.202 had a higher cropping efficiency and G.202 had a higher cumulative yield. G.902 and G.730 produced smaller trees than M.9 but yield efficiency was similar (G.902) or greater (G.730). Five of the Geneva rootstocks have been released for commercial propagation and these include 3 of those in trial at East Malling (G.11, G.30 and G.202).

The Mondial Gala trial compares three of the rootstocks raised at the Vineland Research Station in Canada with the French Pajam 2 rootstock. At the time of planting in March 2000 the tree quality of these bench grafts was very poor in comparison with the trees on Pajam 2. Currently the number of dead or diseased trees for rootstocks V.1, V.3, V.4 and Pajam 2 is 1, 5, 3 and 1 out of 6 respectively. Clearly it is not possible to assess the performance of trees on V.3 rootstock and results for V.4 are based on only 50% of the trees originally planted. In view of the tree health problem it is likely that the trial will be terminated in the coming winter. V.4 was more vigorous than Pajam 2 with a greater number and length of shoots. V.1 was similar in these respects to Pajam 2. The yield efficiency of both Vineland stocks was similar but tended to be lower than for Pajam 2.

A new trial was planted on 8 May 2003 (Plot EE 195) to evaluate new rootstocks from the breeding program at East Malling. A similar trial was planted in the organic area at East Malling (Plot GE 182) in order to evaluate the performance of new rootstock selections under conditions that are generally more restrictive in terms of moisture and nutrient availability (Project TF141). Trees of Queen Cox on 3 new rootstock selections (AR 486-1, AR 295-6 and AR120-242) are being compared with M.9 and on Bramley's Seedling 4 new rootstock selections (AR 628-2, AR 69-7, AR 360-19 and AR 801-11) are being compared with M.27. The trees have yet to establish after being planted late and being subject to an exceptionally hot, dry summer. It was interesting to note however that Bramley trees on M27 under conventional management achieved higher shoot numbers and lengths than under organic management.

Pear rootstock trials planted at HRI-East Malling

Results with C132, a quince rootstock from the HRI breeding programme, in the two trials at East Malling have been contradictory particularly as regards the vigour of the rootstock in comparison with EMC. In the younger trial there was no greater dwarfing effect of C132 on either Conference or Comice and, though cumulative yield of class 1 fruit above 65mm was higher than for EMC, yield efficiency was lower. In an older trial Conference on C132 was less vigorous than EMC and though cumulative yield was lower the yield efficiencies of C132 and EMC were the same. Tree density may be a factor influencing the comparative vigour of Conference on the different stocks. In the older trial the trees were more densely planted than in the younger trial.

BP30 (a promising Swedish *Pyrus* selection) has proved more vigorous than EMC but yield in 2003 and yield efficiency was lower. Although for Conference BP30 resulted in a larger tree volume compared with EMC, on Comice tree volume was less.

QR708/2, a dwarfing *Pyrus* selection from the HRI programme, continues to be more vigorous than EMC but has a lower cumulative yield and yield efficiency and appears to be incompatible with Conference with the result that 50% of the trees have died.

Pyrus scion varieties (Gieser Wildeman, Delbuena and Dolacomi) are being tested as rootstocks for Conference and Comice along with the *Pyrus* rootstock 'Pyrodwarf' and the quince rootstock Sobu. All *Pyrus* rootstocks were more vigorous and less yield-efficient than EMC and reduced accumulated yields of Comice although only 'Dolacomi' reduced accumulated yields of Conference pears. There is an incompatibility problem with Sobu and as a result 30% of the Comice and 60% of the Conference trees have died.

In a commercial orchard in East Kent Concorde trees on EMH continue to be less vigorous than on EMA and surprisingly Conference trees on EMH continue to be smaller than those on EMC. Yields and mean fruit weight of Concorde on EMA and EMH were similar although EMH tended to be more yield-efficient. Yields of Conference were lower (by 45%) on EMH compared with EMC and mean fruit weights were similar.

Technology Transfer

An overview of the pear rootstock trialling being undertaken within project TF134 is to be presented at the HDC Pear Research Walk scheduled at EMR scheduled for 26 August 2004.

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