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AUTHENTICATION

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

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GROWER SUMMARY

Headline

- There is a strong need for new or improved rootstocks for apples, pears, plums and cherries that are dwarfing, precocious, high yielding and offer some measure of drought tolerance.
- UK trialling of promising UK and overseas material should continue.
- Technology transfer should be improved.

Background and expected deliverables

Rootstocks are a vital part of the currently used growing systems for tree fruits. The rootstocks widely used in tree fruit production have been grown for decades but they all have some limitations. Breeding progammes in different parts of the world have generated a number of promising rootstocks in recent years, which are becoming increasingly available to growers.

This review aimed to answer the following questions:

1. What are the advantages and shortcomings associated with existing rootstocks? This includes either those derived from EMR or those currently available from other breeding programmes.
2. If the shortcomings of the currently available rootstocks were remedied, would they be of immediate benefit to fruit growers? Furthermore, will future changes in the world's top fruit industry create a need for new combinations of rootstock attributes not currently perceived as important?
3. Is the current rootstock breeding work at EMR still required or can the UK industry rely on other programmes to breed new rootstocks, which meet our objectives?
4. Is the EMR rootstock breeding programme conducted efficiently and is it appropriately focused on the current and future needs of UK growers?
5. Do overseas rootstock breeding and selection programmes offer the promise of improved rootstocks in the future, and will these provide any significant benefits for UK growers?
6. Are the UK (currently EMR) programmes, which are focused on testing foreign rootstocks in the UK, appropriate to the needs of UK growers and are they organised well and implemented correctly?

Summary of the project and main conclusions

This review held meetings with both a group of industry representatives and EMR staff currently involved in rootstock research. These meetings helped to provide some of the answers to the questions posed above by canvassing opinions on the need for new fruit tree rootstocks in the UK industry, assimilating views on the existing HDC funded projects targeted on rootstocks and appraising the work currently being carried out. It also allowed them to offer suggestions for the future.

Apple rootstocks

Consultations indicated that the UK apple industry places priority on the following:

Requirements in new apple rootstocks

- A rootstock with intermediate vigour between M27 and M9, which performs well in the nursery and which produces precocious and consistently abundant yields of high quality fruits of the marketable size grades.
- A replacement rootstock in the M26 vigour category, which does not suffer from burr knotting, poor calcium uptake or physiological disorders. This rootstock should also induce precocious and abundant yields of high quality fruits.
- In the medium term, dwarfing rootstocks will be needed which can tolerate drought and weed competition better than the existing dwarfing rootstocks.
- In the long term, climate change may bring a need for apple rootstocks that are tolerant or resistant to fireblight.

Breeding and initial screening of new apple rootstocks by EMR

- Currently, all of the funding for making new crosses of apple rootstocks is derived from a Defra-funded project on Marker Assisted Selection.
- The crosses made as part of this project are appropriate for the project's aims and may provide some useful rootstocks as a spin-off for subsequent evaluation as part of the Apple and Pear Breeding Club (APBC), of which HDC is a member, or for the HDC in its own individual rootstock evaluation project.
- New apple rootstock crosses have been made in each of the last four years and some of those produced have already been budded with a scion. The first crops on this new wave of rootstocks should be harvested in 2005.
- A technique to aid rapid evaluation of new rootstocks has been developed, involving the use of columnar scions and minimal land.
- No additional funding is currently warranted in this area. This situation should be reviewed in three year's time, when the Defra project terminates.
- It may be expedient to endeavour to convince the APBC that more of its funding should be diverted to rootstock breeding rather than scion breeding.

Apple rootstock orchard evaluation by the EMR team and growers

- One new rootstock selection, M116, has been released recently from the EMR programme. This is a rootstock with similar properties to MM106 but with very strong resistance to collar rot. This would make an ideal rootstock for cider apple production.
- Almost 100 selections emerging from the first preliminary screen at EMR have been adequately field tested in preliminary orchard trials based at East Malling. Approximately 10 promising rootstocks (with vigour ranging from M27 to M26) have been selected so far from these trials.
- Serious delays have occurred following these initial trials, when attempts have been made to bulk up the promising selections for larger scale trials on grower holdings.
- In the past, field evaluation of a range of Polish, Czech, Russian, German, American, Canadian and Swedish apple rootstocks has been undertaken at EMR. Some showed promise and possibly warrant further evaluation by UK growers.

- Trials on several American and Canadian rootstocks continue at EMR. Several of the American (Geneva) selections show potential.
- A limited number of new selections from abroad should be imported for testing in the UK. These should be chosen mainly from the new rootstocks developed in Poland, Japan and the USA and should focus on the clones likely to fulfill the UK objectives listed above. Consideration should be given to expanding testing of new promising foreign apple rootstocks to cover several grower sites, as well as a trial based at EMR.
- The records and measurements made by the EMR team on the various orchard trials appear to be largely in line with the requirements of the industry. Records of shoot growth have sensibly been abandoned, as they were deemed to be too labour intensive.
- In future apple rootstock trials, scions such as Gala and Braeburn should be considered as well as Queen Cox and Bramley's Seedling.

Pear rootstocks

Consultations indicated that the UK pear industry places priority on the following:

Requirements in new pear rootstocks

- There is a need for increased dwarfing of pear scions to fit them to high-density systems without the need to resort to use of either plant growth regulating chemicals or root pruning.
- Whilst dwarfing quince stocks are the best way forward for scions such as Conference and Comice, most new pear varieties are incompatible with quinces and need the use of expensive interstocks. A fully dwarfing and easy to propagate *Pyrus* stock would be beneficial to provide a much wider range of graft compatibility with new pear varieties, as well as providing better tolerance of drought and alkaline soils.
- New dwarfing rootstocks that improve pear precocity of cropping are vital if pears are to remain economically viable.

Breeding and initial screening of new pear rootstocks by EMR

- The current crossing of pear rootstocks, which is undertaken at EMR, is funded by the Defra project, although some crosses were made prior to this project and were funded as part of the APBC project.
- Most of the crosses made have been of *Pyrus* but some quince crosses have also been included.
- The crosses made as part of this project are appropriate for the project's aims and may provide some useful rootstocks as a spin-off of for subsequent evaluation as part of the APBC or the HDC in its own individual rootstock evaluation project.
- Attempts are being made to speed up the evaluation of the new rootstocks produced by budding with Concorde.
- No additional funding is currently warranted in this area. The situation should be reviewed in three year's time, when the Defra project terminates.
- It may be expedient to endeavour to convince the APBC that more of its funding should be diverted to rootstock breeding rather than scion breeding
- Some interesting crosses between *Malus* and *Pyrus* and between *Pyrus* and *Cydonia* (quince) to produce bi-generic hybrids have been carried out at EMR. Theoretically, these could provide compatible bridge grafts between pear scion varieties and the whole range of fully dwarfing apple rootstocks.

Pear rootstock orchard evaluation by the EMR team and growers

- One new quince rootstock, the dwarfing EMH (previously QR196-16), has been released from the EMR programme. Although inducing poorer precocity than Quince C, EMH is of value in inducing larger fruit size. Trials of EMH on grower sites are also being evaluated.
- Currently, there are several trials in the ground at EMR evaluating EMR selections of *Pyrus* clonal rootstocks. These trials are funded by the APBC programme.
- Very few quince clones are currently in these trials, although one EMR quince selection C132 shows promise in UK and Dutch trials, as being slightly more dwarfing than EMC (Quince C). This stock needs to be bulked up for further testing on grower sites.
- Most of the *Pyrus* rootstock selections are inducing intermediate vigour and are not of significant relevance to UK grower needs. Only one stock QR708-36 shows preliminary promise in inducing good crops on trees of medium size.
- From HDC's viewpoint the trials of most of these *Pyrus* clones are of very low priority. The APBC's goals are different and may warrant continued testing of some of these selections.
- The EMR team is also evaluating, through HDC funding, *Pyrus* and quince rootstocks imported from other breeding programmes abroad. Several of these trials were begun in collaboration with Dutch researchers.
- Trials testing the much publicised German *Pyrus* rootstock Pyrodwarf have shown it to be invigorating and of very poor performance. Although delivering negative results, the trial has served a useful purpose in warning UK growers not to plant this stock.
- The future HDC funded pear rootstock should focus on seeking UK and foreign stocks that meet the UK's specific goals. More emphasis on dwarfing quinces is warranted, with possible trials of C132 on grower farms.

Sweet cherry rootstocks

Consultations indicated that the UK cherry industry places priority on the following:

Requirements in new sweet cherry rootstocks

- The main requirement is for a rootstock that is more dwarfing than either GiSela 5 or Tabel and would control the vigour of trees sufficiently for easy growth within tunnels.
- Dwarfing stocks that are easier to propagate than either Tabel or GiSela are also needed. This should facilitate the production of less expensive trees.
- More minor requirements are for dwarfing rootstocks that are more suited to heavy clay soils (GiSela clones perform poorly in wet soils) and for dwarfing stocks that induce large fruit size.

Breeding and initial screening of new sweet cherry rootstocks by EMR

- There is currently no source of funding for any breeding of sweet cherry rootstocks.
- Some crossing in recent years has been carried out at EMR between the very dwarfing rootstock *Prunus mugus* and *P. pseudocerasus*, which is a parent of Colt. The aim was to produce fully dwarfing stocks, which were easy to propagate. Preliminary evaluation of the resulting hybrids indicates that the hybrid stocks are easy to propagate and are also dwarfing.

Sweet cherry rootstock orchard evaluation at EMR and by growers

- There is currently only a very minimal amount of funding, provided by the Cherry Club, for one sweet cherry rootstock field evaluation.
- This trial compares the most promising dwarfing rootstock selections from breeding programmes abroad. However, the records currently taken on this trial are minimal.
- This trial is one of several trials, all with the same rootstocks and scions, which were planted as part of an international collaboration.
- HDC should support the continuation of this trial and facilitate the UK's collaboration in any future international sweet cherry rootstock trialing initiatives.
- EMR are endeavouring to obtain trees on a new GiSela selection, GiSela 3, which is reported to be more dwarfing than GiSela 5 or 6. Funding to aid the testing of this stock by the industry (recorded by EMR staff) under commercial polythene tunnels is recommended.

Plum rootstocks

Consultations indicated that the UK plum industry places priority on the following:

Requirements in new plum rootstocks

- Rootstocks are required which provide increased dwarfing for plum trees to facilitate production under fully high density systems.
- Rootstocks that induce precocious and consistently abundant yields of large good quality fruits are essential.

Breeding and initial screening of new plum rootstocks by EMR

- There is currently no breeding of plum rootstocks funded at EMR.
- The EMR staff have the expertise to do this should it be required.
- A few clones that were generated as part of an earlier plum scion breeding programme (that was terminated some years ago), may have potential as dwarfing rootstocks.
- Plum rootstock breeding does not currently command high priority, but this situation should be reviewed in 5 years time.

Plum rootstock orchard evaluation at EMR and by growers

- No trials of plum rootstocks are currently in progress at EMR
- EMR staff however, have been asked to monitor one trial planted on an East Kent farm. This trial includes a stock generated in the Crimea region of Russia, named VVA1. This is proving to be a very promising stock in Dutch and other trials.
- A small amount of additional funding is warranted to facilitate the recording of this trial and possibly the residual clones from the breeding programme.
- Trials conducted some years ago at EMR in collaboration with Dutch researchers showed the considerable merits of Plumina as a replacement for Pixy and Ishtara as a replacement for St. Julien A. Both stocks induce larger fruit size than the standards. Renewed attempts to reiterate this message may be warranted.

Financial benefits

The cost of trees forms a significant part of the total cost of establishing an orchard. The costs are further increased by the royalty payments on new varieties and on new rootstocks, most of which are protected by Plant Breeders Rights. Mistakes at planting can prove costly over the 20-year commercial life of an orchard. It is essential therefore that rootstocks choice is based on the best available information. In new orchards relatively small improvements in tree establishment or productivity can, over the life of the orchard provide growers with substantial financial benefit.

Action points for growers

- Think carefully about rootstocks choice at an early stage when planning new orchards. Do not automatically choose specific rootstocks you have used before without considering the alternatives.
- Plan well ahead; some recently introduced rootstocks may be in relatively short supply and need to be ordered well in advance of planting.
- Be prepared to consider planting small demonstration plots of new rootstocks as they become available to gain experience of their habit on your own soils and site.

SCIENCE SECTION

Introduction

Why use rootstocks?

In the past the main reason for using rootstocks for pome and stone fruit trees was to facilitate their propagation. Although easy to propagate from seed, pome and stone fruit scion varieties do not develop into true-to type trees when raised this way. To multiply superior and selected cultivars it is necessary to propagate them clonally, i.e. using a vegetative method. Unfortunately, most scion cultivars are very difficult to propagate by traditional cutting techniques and it became standard practice to propagate them by grafting or budding onto rootstocks. Several centuries ago the majority of rootstocks were raised from seed or occasionally dug up as suckers from the bases of trees in existing orchards. The attributes required of such rootstocks were ease of propagation from seed, rapid and good establishment in the nursery, strong growth, graft compatibility with the chosen scions and freedom from excessive suckering.

In recent years, as techniques of propagation have developed and improved, methods have been found to propagate scions on their own roots. By careful control of the rooting environment it is now possible to propagate many apple cultivars from either hardwood or softwood cuttings. Moreover, with the development of micropropagation technologies, it is now possible to propagate most pome and stone fruit cultivars on their own roots. Advocates of these new technologies have often suggested that tree fruit production should shift away from the use of rootstocks towards production of own rooted trees, as such trees should be cheaper to produce. This goal of cheaper trees on their own roots however has yet to be realized. Moreover, trees on their own roots frequently exhibit severe shortcomings (e.g. slow establishment following planting, excessive vigour, small fruit size, suckering and poor anchorage. Also, they fail to offer any of the many advantages that modern selected clonal rootstocks now provide to the producer of temperate fruits (see below).

Benefits achievable when using selected clonal rootstocks

As well as proving a means of propagating scion cultivars, rootstocks can offer the following additional benefits:

- Manipulation of tree vigour
- Induction of precocious flowering and cropping
- Induction of increased cropping
- Improvement of fruit size and quality
- Adaptation of the scion tree to different soil types (e.g. sands, clays, alkaline) and the stress problems associated with such soils
- Tolerance/resistance to soil borne pests (e.g. nematodes and woolly aphids)
- Tolerance/resistance to soil borne diseases (e.g. collar/crown rot)
- Tolerance to damaging winter frosts and root or trunk death
- Tolerance to drought and/or summer high temperature stress

In addition to the above characteristics, other rootstock attributes are frequently desired, such as:

- Ease of propagation and good nursery performance
- Tolerance/resistance to aerial pathogenic diseases (e.g. fireblight)
- Tolerance/resistance to damaging pests (e.g. stem borers)

These additional attributes are invariably necessary in the scion as well, as there is only minimal evidence of any tolerance/resistance being transferred from rootstock to scion. One possible exception, still not fully proven, is the improved survival following fireblight attack of apple trees worked on red-leaved clonal rootstocks, such as Budagovski 9 (B9).

Choosing the appropriate rootstock

No single rootstock carries all of the beneficial attributes listed in the above section. It is necessary, therefore, to identify and prioritize the required attributes and then endeavour to select a rootstock which has characteristics closest to those required.

The ranking of priorities will inevitably alter, depending upon:

- Site and soil conditions- this will influence the rootstock choice in terms of its tolerance/resistance to biotic stress factors (i.e. the anticipated pests/pathogens) and to abiotic stresses (i.e. temperature extremes, drought, temporary water logging)
- Planned training and management system – this will influence the rootstock choice in terms of its effects on scion vigour and habit
- Anticipated severity of pest and disease incidence
- Fruiting characteristics of the scion cultivar – this will influence the rootstock choice (e.g. shy cropping and large fruit size where a rootstock which promotes precocity and abundance of cropping is required, to the other extreme where scions frequently over crop and bear too small fruits; in this case a precocity inducing rootstock merely exacerbates the scion's problem)

Other factors influencing the choice of rootstock are:

- Its cost in relation to other rootstocks
- Its availability to nurseries
- Its availability as a fully healthy clone (e.g. freedom from viruses)

Rootstocks available to the UK fruit grower

East Malling rootstock selections

Selection and breeding projects, which commenced at East Malling Research Station in 1914 and which have continued at differing degrees of intensity until the present day, have been successful in providing clonal rootstocks for apples that offer a range of scion vigour control. A more limited range of stocks for pears and plums and several stocks for sweet cherries have also been produced and released by East Malling.

Only a selected few of the full East Malling (EM) range of stocks continues to be available to fruit growers from UK nurseries or nurseries on mainland Europe. Nurserymen have reduced the range of stocks on offer in response to changes in demand.

The EM-produced rootstocks currently on offer in Europe are:

Apple: M27, M9, M26, MM106, M116 (AR 86-1-25), MM111 and M25

Pear: QC (EMC), EMH (193/16) QA (EMA)

Plum: Pixy, St. Julian A, Brompton, Myrobalan B

Cherry: Colt, F12/1

Other selections made by East Malling, mainly invigorating types, have drifted out of commerce and are now generally only available in Europe from specialist gene banks.

Commercial rootstocks produced at research and development centres other than EMR

Fruit growers abroad realized, more than fifty years ago, that although the East Malling selected rootstocks often performed well in their climatic and soil conditions, this was not always the case. Often, these foreign growers required rootstock attributes that were different or in addition to those provided by the EM selections; in particular attributes associated with tolerance/resistance to biotic and abiotic stress factors. This stimulated the initiation of rootstock breeding and selection programmes in other countries. In recent years, many rootstocks resulting from these breeding and selection programmes have become available to nurseries and fruit growers, both in the UK and on the continent. The most popular and the most widely available of these foreign releases are the following:

Apple: P22 from Poland; sub clones of M9 (e.g. Pajam 1 and 2, from France; Nicolai 29 from Belgium; NAKB 336 and Fleuren 56 from the Netherlands; and Burgmer selections from Germany), Budagovsjki 9 (B9) (from Russia); J-TE-E, J-TE-F, J-OH-A from the Czech Republic; Supporter 1, Supporter 2, Supporter 4 and Jork 9 from Germany; Bemali from Sweden.

Pear: Adams from Belgium; Sydo, Pyriam (OH11) and BA 29 from France; OHF 332 from the USA.

Plum: St. Julien d'Orleans, Plumina (Ferlenain), Ishtara (Ferciana), P-813, GF8-1, Fereley/ Jaspi, Julior/Ferdor from France; Wagenheim from the Netherlands; MrS2/5 from Italy; Citation from the USA; Ademir, Adara, Tetra, Penta from Spain.

Cherry: GiSela 5, GiSela 6, Weiroot 13, Weiroot, 72, Weiroot, 158, Weiroot 154 from Germany; Tabel from France; MaxMa 14 from the USA; PHLA from the Czech Republic; Damil, Inmil from Belgium.

Materials and methods

The research panel met with a group of industry representatives to gauge opinions on the need for new fruit tree rootstocks by the UK industry and sought their views on existing HDC funded projects targeted on rootstocks. This was supplemented by telephone interviews. A further meeting was held with key staff at East Malling Research, namely Mr. Ken Tobutt, Dr Kate Evans, Mr David Johnson and Ms Jane Spencer. These reviews helped to appraise existing work carried out at EMR. This was integrated with information from published work elsewhere in the world on rootstocks, together with the researcher's' knowledge of overseas research programmes and associated developments.

Results and Discussion

This section considers each of the questions set out within the 'Aims of the project' (see Background and expected deliverables in the Grower summary) and discusses some of the implications arising from them.

What are the advantages and shortcomings associated with existing rootstocks?

The answer to the above question was provided by integrating the opinions expressed by a representative group of industry experts, including growers, managers and advisors (see Appendix I for the minutes of this meeting) with those of the researchers who worked on this project. This group of industry experts met in November 2004.

The combined comments and suggestions regarding the advantages and shortcomings of the most popular rootstocks are as follows:

Apple:

M27 (origin EM) has merits for use with vigorous triploid varieties (such as Jonagold or Bramley) planted on fertile soils with adequate moisture reserves. However, it is generally too dwarfing for use with most scion cultivars planted on UK soils. It induces very high cropping efficiency and, unless thinning is very rigorous and irrigation plentiful, small fruit size is a common problem. M.27 demands the use of some form of support system to aid tree anchorage, which adds significantly to the cost of orchard establishment.

P22 (origin Poland) if provided with adequate irrigation and fertile soils, such as those in many parts of the Netherlands, produces trees intermediate in vigour between M27 and M9. Precocity and productivity are good. However, if planted in poorer conditions and given no irrigation trees grow very poorly and produce very small fruit size. Some inconsistency of performance has been noted between clones of P22 and this seems to be associated with the method of propagation (conventional stooling or micropropagation). There has been little use of P22 in UK orchards to date.

M9 (origin France) will continue to be the most important rootstock in the medium term. Its main merits are its ability to dwarf scions, the induction of precocity and yield efficiency and its tendency to induce large fruit sizes. Its main defects, namely sensitivity to fireblight, woolly aphid attack to the roots and winter cold damage, do not limit its use in the UK, as they do in parts of the Southern Hemisphere and the USA. However, slight changes in the UK climatic conditions, if coupled with limitations on water supply for irrigation, may mean that some or all of M9's known

problems could become of critical importance also in the UK. Although M9 is slightly difficult to propagate, this is not perceived to be a major limiting factor to its use. Trees on M9 are poorly anchored and require support via individual stakes or some form of trellis/hedgerow system. Support systems for trees on M9, as with M27, are expensive and can represent up to one third of the planting costs.

Although there are several widely available clones of M9 they are all similar in terms of sharing the above disadvantages of the traditional UK clone (M9 EMLA). For the most part these clones are very similar in vigour and thus do not satisfy the need for a stock intermediate between M27 and M9 in vigour. The only exception in this respect is the more dwarfing clone Fleuron 56, but this may produce slightly smaller fruits than the other clones. The main advantages of the various M9 clones are that most are easier to propagate than the traditional M9 EMLA.

Budagovski 9 (origin Russia) produces trees of varying vigour depending upon soil and climatic conditions. However, trees on the stock are usually slightly more vigorous than trees on M9 EMLA. Although popular in parts of the USA and available from European nurseries it has not been planted commercially in the UK. USA evidence suggests that it may confer some tolerance to fireblight in scions worked upon it.

M26 (origin EM) is popular on some UK sites as a rootstock for Gala and for Bramley, on account of its slightly increased vigour (in comparison with M9). It does induce lower cropping efficiency than M9. It also produces burr knots, especially if planted with more than just a few centimetres of its shank above the soil surface. There are also reports that the uptake and movement of calcium into the fruits of trees on M26 is sometimes poorer than on other popular rootstocks. M26 is better anchored than M9 but still requires stakes or other supports on exposed sites. It is the most popular semi-dwarfing rootstock in parts of the world where drought or winter cold are a problem.

MM106 (origin EM) is the best semi-vigorous rootstock in terms of ability to induce heavy cropping. In past years, it was widely planted in the Southern Hemisphere. However, its sensitivity to collar rot means that it is inappropriate for use on heavy clay or other poorly drained soils, where this disease is likely to be a problem. Many cider trees raised on MM106 have been lost due to collar rot. M7, which is of similar vigour has always proved more popular in the USA.

MM111 and M25 (origin EM) are only appropriate for the production of trees for cider apples or juice production. On all but the poorest soils vigour on these two rootstocks is too strong for modern management systems.

Pear:

All quince stocks exhibit graft incompatibility with the majority of pear scion varieties (e.g. Abate Fetel, Williams BC, D'Anjou, Packham's Triumph) and require an interstock of Comice or some other compatible cultivar. Fortunately, Comice and Concorde show no incompatibility symptoms and only slight problems are experienced with Conference in very stressful situations. Sensitivity to winter cold damage, a problem with most quince rootstocks, is not usually a significant problem in UK climatic conditions.

QC (origin EM) is the most dwarfing quince rootstock currently available for pear production. However, vigour on QC (EMC) is still too great to allow adequate control of the tree size of cultivars such as Comice. Even with the less vigorous Conference, growth can be excessive on rich fertile soils. Fruit size of scions such as Conference grafted onto QC is often less than desired. Trees on QC are poorly anchored and perform poorly if planted on alkaline soils.

EMH (origin EM) a newly released quince, has vigour intermediate between QC and QA and with some cultivars can prove useful in inducing slightly larger fruit size. Its main disadvantage is that it induces poorer precocity of cropping than QC. As with QC, growth is poor on alkaline soils.

Adams (origin Belgium) is a quince clone that induces vigour intermediate between that on QC and QA. It is preferred, particularly for Conference, in parts of continental Europe, where Conference trees on EMC sometimes exhibit stress and slight symptoms of incompatibility. As with QC, growth is poor on alkaline soils.

QA (origin EM) and the very similar French selection **Sydo (origin France)** are both Angers type quince stocks, that are only suited to use with traditional bush, or vase shaped trees. The tree vigour on these rootstocks is too great to allow their use for more intensive systems of planting. As with QC, growth is poor on alkaline soils.

Provence BA29 (origin France) is not used in the UK on account of its strong vigour (greater than on QA and Sydo). It is mainly of value in hotter drier climatic conditions, such as the south of France and Italy, where it is capable of withstanding stressful conditions much better than the aforementioned quince clones. Trees on BA 29 are better than most other quinces in tolerating some soil alkalinity

Pyrodwarf is not a quince but is a selection of the pear itself (*Pyrus communis*). It was released several years ago as the first fully dwarfing *Pyrus* rootstock. Results have proved disappointing however, with vigour much greater than anticipated and poor fruit size on some sites. Despite its widespread and, in hindsight, premature planting in the USA it seems unlikely that it will prove to be the first fully dwarfing *Pyrus* rootstock for pears.

OHF 332 (origin USA) is an invigorating *Pyrus communis* clonal stock that is used to a small extent in France. Its only real advantage is its compatibility with all pear varieties. It is easier to propagate than many other *Pyrus* clones. However, it induces poor yields and often poor fruit size until the trees are fully mature.

Cherry:

GiSela 5 (origin Germany), which has been widely available in the last 10 years, is proving an excellent rootstock for the production of semi-dwarfed sweet cherries grown in orchards planted either without rain protection or beneath rain shelters. However, the stock is still rather too invigorating for use in production of cherries under standard-sized Spanish tunnels. This stock is also sensitive to root rots and tree death may be a problem if planted on poorly drained clay soils. Induction of flowering and cropping is excellent on GiSela 5 and in most cases this is an advantage. However, with small-fruited cultivars, such as Sweetheart, cropping may prove excessive and fruit size less than desired by the markets. Propagation is quite difficult and most GiSela 5 rootstocks are micropropagated.

Tabel (Edabriz) (origin France) is of similar vigour to GiSela 5 and is also excellent in inducing precocious and abundant cropping. However, this stock needs careful establishment during the first few seasons in the orchard. If subjected to stressful conditions or severe attacks of cherry black fly (*Myzus cerasi*) trees on Tabel may decline to grow and become stunted and unproductive.

GiSela 6 (origin Germany) is more invigorating than the aforementioned rootstocks, but has similar beneficial effects on precocity and yield abundance. It is preferable on slightly poorer soils and where more traditional systems of cherry tree training are employed. As with GiSela 5, it dislikes wet soils and may suffer from root rots in such conditions.

Colt (origin EM) is more invigorating than any of the above rootstocks and is only suitable for the production of semi-standard trees. It may still have benefits for use with weak growing and heavy cropping varieties, such as Sweetheart, especially when grown on soils with lower than average fertility. Nurserymen appreciate Colt for its extreme ease of propagation. However, in some situations Colt has induced only poor yield efficiency in comparison with the more modern dwarfing rootstocks.

MaxMa 14 (origin USA) is slightly more dwarfing than Colt but is only suitable for planting on very well-drained sandy soils on sites experiencing hot dry summers. It is not recommended for use in the UK. In some situations trees on MaxMa 14 exhibit graft incompatibility with sweet cherry scions.

Plum:

Plumina (Ferlenain) (origin France) is the most dwarfing plum stock that is currently commercially available. Vigour of Victoria on Ferlenain proved to be less than that on Pixy in early UK and Dutch trials (Webster and Wertheim, 1993). However, the vigour of other varieties grown in subsequent trials using this rootstock was not so dwarfing. It performs poorly in dry, stressful soil conditions and is incompatible with gages. Fruit size is generally very good on this rootstock.

Pixy (origin UK) is slightly more invigorating than Ferlenain but trees are still too large for effective use in modern high-density systems. Nonetheless, Pixy has consistently proved the most yield efficient rootstock in trials in Scandinavia. Fruit size of scions on Pixy is sometimes reduced.

Ishtara (Ferciana) (origin France) is similar in vigour to St. Julien A, but has consistently induced larger fruit sizes in European trials with a range of plum cultivars.

St Julien A (origin EM) remains the most popular rootstock in the UK for plums and is widely used in other parts of Europe. It produces semi-vigorous trees that crop quite productively. It is not, however, very suited to intensive systems of production.

St Julien d'Orleans (origin France) is very similar in performance to St Julien A.

Wagenheim (origin the Netherlands) has proved quite dwarfing in some trials conducted in the Netherlands but this response has not been consistent and in Norwegian trials it proved quite invigorating. It does induce good yield productivity.

Most of the other rootstocks for plums available from European nurseries, e.g. P-813, GF8-1, Fereley/ Jaspi, Julior/Ferdor, Ademir, Adara, Tetra and Penta, are more invigorating than the aforementioned stocks. They are only suited to the production of standard trees, such as those grown in France for mechanical harvesting and prune production. Citation, although sometimes dwarfing, also shows incompatibility symptoms with many scion varieties.

Short and long term future UK requirements in new rootstocks

Taking account of the various shortcomings of the existing, commercially available rootstocks and also the opinions expressed by the representative group of industry experts interviewed and those of the researchers, the short and long-term rootstock requirements are believed to be as follows:

Apple:

Short/medium term objectives

1. One or more rootstocks with vigour intermediate between M27 and M9, which has/have yield performance similar to M9 but which also induce large fruit size and require no additional irrigation.
2. Dwarfing rootstocks with much better anchorage, so that the costs of tree support can be greatly reduced.
3. A rootstock with vigour similar to M26 but with improved yield efficiency and none of M26's disadvantages.

Long term objective

1. Rootstocks of similar vigour to M27 or M9 but which are better able to tolerate drought and weed competition (e.g. for future systems where herbicides are not used and no supplementary irrigation is provided i.e. organic or similar protocols of production).

Pear:

Short/medium term objectives

1. A quince stock with vigour less than QC and which induces large fruit sizes.
2. Dwarfing rootstocks, which induce improved yield precocity in scions.

Long term objectives

1. Clonal quince stocks with improved tolerance of drought and alkalinity.
2. Clonal quince stocks with improved graft compatibility.
3. Dwarfing and semi-dwarfing *Pyrus* rootstocks, which exhibit ease of propagation and good induction of yield precocity and productivity together with good fruit size and quality.

Cherry:

Short/medium term objectives

1. A stock more dwarfing than GiSela 5 or Tabel, which is suitable for fruit production under Spanish tunnels and which has all of the other merits of GiSela 5.
2. Stocks similar to GiSela 5 and 6 but which are much easier to propagate.

Long term objective

1. Stocks similar to GiSela 5 and GiSela 6 but which exhibit better tolerance to soil borne fungal diseases.

Plum:

Short/medium term objective

1. A fully dwarfing rootstock which exhibits good graft compatibility with all of the popular scion varieties and which induces heavy yields of large fruit sizes.

In all the above cases, the new rootstocks must induce good precocity and yield abundance coupled with good fruit size

Rootstock breeding and selection programmes throughout the world

Many of the overseas rootstock breeding programmes for apple, pear, plum and cherry which were active 10 or more years ago have ceased in recent years, although field evaluation of many of the selections produced is often still continuing.

Existing breeding and evaluation programmes and stocks released

Apple rootstock breeding and selection programmes

Details of the programmes that are either still active or have only ceased in recent years are shown in Table 1 below:

Table 1: Apple rootstock breeding and selection programmes

Country	Centre	Research Leader	Breeding still in progress (B) or selection and development only (SD)	Clone designations
USA	Geneva Agricultural Research Centre, Cornel University, New York State	Dr T. Robinson	B	G or Geneva prefixes
Japan	Apple Research Centre, NIFTS, Japan	Prof. J. Soejima	B	JM series
Poland	Research Institute, Skierniewice	Dr T. Jacubowski	B	P prefixes
Russia	Michurin Institute	Dr I.A. Kuldoshin Dr. V.A. Potapov	B?	B prefixes originally, now simply numbers
Germany	Dresden Pilnitz	Dr Manfred Fischer	SD	Supporter Series
New Zealand	HortResearch, Hawkes Bay	Dr Stuart Tustin	B	Non yet released or named
Czech Republic	Independent breeder Now retired	Mr Dvorjak	SD	J-TE- prefixes and J-OH-A

Ukraine	UAAS, Kiev	Dr O.D. Chyzh	B	IC prefix
Romania	Pitesti Institute	Dr. C. Mazilu	?	Voinesti clones

Pear rootstock breeding and selection programmes

Details of the programmes that are either still active or have only ceased in recent years are shown in Table 2 below:

Table 2: Pear rootstock breeding and selection programmes

Country	**Centre**	**Research Leader**	**Breeding still in progress (B) or selection and development only (SD)**	**Clone Designations**
Germany1	Geisenheim	Dr H. Jacob	B ?	Pyrodwarf and others
Germany2	Dresden Pilnitz	Dr Manfred Fischer	SD	Not yet named
France	INRA, Angers	Dr Marie-Helene Simard	B	Brossier Series; Retuziere series Pyriam and others
Spain	Cabrils, Mas Badia and Lleida	Drs Dolcet-Sanjuan, Claveria, Bonany, Iglesias and Asin	B	As yet no clonal designations
Lithuania	Insit of Hort., Babtai	Dr D Kviklys	SD ?	K prefixes
USA	Hood River Research Center, Oregon	Dr E Mielke	SD	Horner Series

Cherry rootstock breeding and selection programmes

Details of the programmes that are either still active or have only ceased in recent years are shown in Table 3 below:

Table 3: Cherry rootstock breeding and selection programmes

Country	**Centre**	**Research Leader**	**Breeding still in progress (B) or selection and development only (SD)**	**Clone Designations**
Germany	Justus Liebig University, Giessen and Ahrensburg	Originally -Dr Hanna Schmidt & Prof Werner Gruppe	SD	GiSela Series

	Now run by commercial nursery	Currently -Dr Sabine Franken-Bembenek		
Germany	Weihenstephan, Munich	Not now known staff retired	SD	Weiroot Series
Germany	Dresden Pillnitz	Now retired Dr Birgitte Wolfram	SD	PI-KU series
Czech Republic	Holovousy	Dr J. Blazek	B?	
France	INRA, Bordeaux	M. Claverie	SD	Tabel
Denmark	Odense	Dr O. Callesen	SD	Dan designations

Plum rootstock breeding and selection programmes

Details of the programmes which are either still active or have only ceased in recent years are shown in Table 4 below:

Table 4: Plum rootstock breeding and selection programmes

Country	**Centre**	**Research Leader**	**Breeding still in progress (B) or selection and development only (SD)**	**Clone Designations**
France	INRA Bordeaux	previously Dr R. Renaud	B?	GF prefixes
Spain	Zaragoza	Dr. M. Moreno	B?	Penta, Tetra and others
Russia	Crimea region	V. Eremin	B	Various including VVA-1
Italy	Pisa	Drs Massai and Loreti	B?	Various including Sirio, Mr.S.2/5

Foreign rootstocks that appear, on existing evidence, to fulfill some or all of the current UK rootstock objectives

The researchers believe the following rootstocks, produced in breeding and selection programmes abroad may fulfill some of the UK's rootstock objectives. In some cases these have already undergone preliminary UK evaluation and now require more widespread field testing. In other cases, where no previous UK testing has been undertaken, the authors recommend that the stocks are imported and raised for initial orchard trialing in statistically designed experiments.

Apple

Breeding Programme	Rootstock Clone(s)	Attributes of clone	Trials suggested	
			EM trial	Grower trial
EM, UK	**M116 (AR86.1.25)**	MM106 vigour and yield performance but very resistant to collar/crown rots. Possible for cider trees?	Already completed tests	Yes
	AR 801.11	M26 vigour but better productivity	Screening trial completed; new trial planted	Yes
	AR 680.2	M9 vigour or slightly less; but better productivity	Yes	Yes
	AR295.6	Vigour slightly less than M9; good yield efficiency	Already in second stage trial at EM	Yes
	AR.852.3	Vigour < M9 but > M27 good yield efficiency	Possibly – only screening trial to date	Possibly
	AR 69.7	Vigour similar to M27	No further test warranted at EM	Yes on good site possibly for Bramley
	AR628.2	Vigour similar to M27	No further test warranted at EM	Yes on good site possibly for Bramley
	AR672.1	Vigour slightly more than M27 and better fruit size	No further test warranted at EM	Yes
	M.20	Vigour similar to M27 but better fruit size	No further test warranted at EM	Yes
Poland	**P22**	Vigour < M9 but on good soils > M27	Tests already completed	Yes
	P 59 and possibly P64	Vigour slightly greater than M27; good yield efficiency	Yes	Possibly
	P numbers 62, 63, 65 and 66	Vigour between M9 and M27	Yes	Possibly
Czech Republic	**J-TE-E**	Vigour less than M9 but greater than M27 and good yield efficiency and fruit size	Already completed tests	Yes
	J-TE-G	Vigour slightly greater than M27; performs well with Jonagold in Belgium	No	Yes
Russia	**B146**	Vigour slightly greater than M27; performed well in Belgium	No	Possibly
Germany	**Jork 9**	Vigour between M26 and M9; better yield efficiency and tolerates drought and weed	Already completed tests	Yes

		competition well – suitable for organic systems?		
USA	**G 41**	Vigour slightly less than M9; performing well in European trials	Yes*	Possibly
Japan	**JM Series (numbers 1,5 and 8)**	Several clones which are reported to be both dwarfing and resistant to woolly apple aphid	Yes*	No

* subject to ability to import and plant out healthy materials

Pear

Breeding Programme	**Rootstock Clone(s)**	**Attributes of clone**	**Tests recommended**	
			EM trial	**Grower trial**
EM, UK	**C132**	Slightly more dwarfing than QC	In existence already	Yes
	QR selections	Dwarfing quinces of unknown graft compatibility	Yes	No
	Pyrus x Malus hybrids	Compatibility with apple rootstocks – test as interstocks	Yes	No
	QR selections	*Pyrus communis* selections with QR 708.36 as one parent	Yes	No
Lithuania	**K quince selections**	Dwarfing and cold tolerant	Yes*	No
USA	**Horner Series**	Potentially dwarfing *Pyrus* selections	Yes*	No
France	**-**	Any promising dwarfing *Pyrus* selections	Yes*	

* subject to ability to import healthy materials

Cherry

Breeding Programme	**Rootstock Clone(s)**	**Attributes of clone**	**Tests recommended (Yes or No)**	
			EM trial	**Grower trial**
EM- UK	**Hexaploid Colt**	More dwarfing than Colt;	No	Yes with 'Sweetheart'
	P. mugus x P. pseudocerasus hybrids	Dwarfing and easy to propagate according to preliminary assessments	Yes	No
Giessen	**GiSela 3**	More dwarfing than GiSela 5	Yes	Yes (under Spanish tunnels)

Plum

Breeding Programme	Rootstock Clone	Attributes of clone	Tests recommended	
			EM trial	Grower trial
UK-EM	**Several PR clones**	Dwarfing residue of selections from Richard Jones' scion breeding programme	Yes	No
France	**Plumina**	Dwarfing and good fruit size but some drought sensitivity	No -Already undertaken 10 years ago	Yes
France	**Ishtara**	Similar vigour to St Julien A but larger fruit size	No -Already undertaken 10 years ago	Yes
Victor Eremin in the Crimea region	**VVA-1**	Very dwarfing	Yes	Yes

The East Malling Rootstock breeding programme

Is it needed or can we rely on rootstocks produced in other programmes?

It is appropriate to question whether breeding of new rootstocks at East Malling Research is required, or whether breeding programmes in progress elsewhere in the world can satisfy the UK's need for new apple and pear rootstocks.

Apple

Although there are several rootstock breeding programmes currently active worldwide, the objectives of these programmes usually differ significantly from the current UK requirements noted above. For instance all of the rootstock breeding programmes based in eastern and central Europe, as well as in the USA focus very heavily on tolerance to winter cold injury, which is not a prime objective for UK growers. Also, fireblight is a major objective of the apple rootstock breeding programme in the USA and unless this disease becomes more serious in the UK this cannot be considered a major UK objective. Similarly, a Japanese programme of rootstock breeding has concentrated on resistance to woolly aphid in dwarfing apple stocks, which again is not currently of paramount importance in the UK.

It can be argued, therefore, that few if any of the overseas apple rootstock breeding programmes are focused on the objectives most critical to the success of UK apple growers and that a UK-based programme would be expedient for the future. Nevertheless, although the overseas programmes for apple are not necessarily focused on UK needs, there is a strong chance that some of the UK's requirements may be satisfied by rootstocks produced in these programmes and it will remain important to evaluate the most promising foreign stocks under UK conditions. The above considerations need to be taken into account when deciding whether to prioritize apple rootstock breeding above or below that of rootstock breeding for the other species.

Pear

The majority of programmes aimed at breeding new pear rootstocks worldwide are focusing on producing clones of *Pyrus communis* (the European or Common pear) and not quince clones. This is because quince stocks are insufficiently winter hardy in the USA and Central and Eastern Europe and pose additional problems of graft incompatibility with most of the scion varieties currently popular abroad. Very few new quince stocks are being produced in overseas breeding programmes. Most of these programmes of rootstock breeding for pears are therefore not focused on the objectives important to UK growers. A strong case can be made for a pear rootstock breeding programme continuing at East Malling. The overall priority of pear, in relation to apple, cherry and plum needs, to be taken into account however.

Sweet cherry

Overseas breeding programmes for sweet cherry rootstocks have proved very successful in recent years with the release of promising Gisela and Weiroot clones from Germany, as well as other stocks of slightly less promise from the Czech Republic. Taking this into account, it might appear that there is little need for a re-vitalised UK sweet cherry breeding programme. However, it should be noted that the programmes based at Giessen/Ahrensburg (GiSela), Munich (Weiroot) and Dresden all ceased breeding some years ago and are now relying on a diminishing backlog of stocks produced in earlier years. It is very unlikely that the desired fully dwarfing sweet cherry rootstock will emerge from these residual selections. A strong case can be made, therefore, for a UK breeding initiative focused on increased dwarfing coupled with improved propagation.

Plum

There has been extensive breeding of new rootstocks for the domestic type of plums conducted in Europe (mainly France and Spain) over the last several decades. Unfortunately, most of the stocks have been bred for resistance to unfavourable soil conditions (drought, waterlogging, alkalinity) and almost none of the clones produced are sufficiently dwarfing for the UK's requirements. Only VVA 1 produced in the Crimea region and Plumina from France show any promise of providing the degree of dwarfing required. A case can be made therefore that breeding of new plum rootstocks is of importance and should be conducted in the UK.

Is the East Malling Research rootstock breeding programme efficiently conducted and appropriately focused for the current and future needs of UK growers?

Most of the comments made in this section are derived from a meeting held between the researchers and the EMR team of breeding and pomology scientists. The minutes of this meeting are included in Appendix B.

Apple

Until relatively recently, most of the new EMR apple rootstocks were clones produced many years ago by Dr Ray Watkins, a former Head of Department at EMR although a few selections bred by Mr Ken Tobutt form the basis of one current orchard trial. The EMR breeding team is currently funded to produce new apple rootstocks as part of a Defra programme focused on marker assisted selection (MAS) within rootstocks. The apple rootstocks produced in this programme should slowly feed their way down via the Apple and Pear Breeding Club initiative (of which HDC is a partner) and will, if sufficiently promising, be selected and become available to UK growers in the

fullness of time. A novel technique of screening these stocks, introduced by Mr Tobutt, using a columnar scion variety, seems very worthwhile in that it saves on costs for land usage, which are extremely high at EMR. It would appear that the evaluation of stocks produced as part of the Defra programme is being progressed efficiently.

Unfortunately, the scale of this apple rootstock breeding is very small and it can be argued that it is not sufficient to have a strong probability of producing new rootstocks with the desired combinations of attributes. It can also be argued that the parents chosen in the crosses made are not always entirely appropriate for the UK's main objectives. Nonetheless, these are small criticisms and for the most part the parents seem very worthwhile. Mr Tobutt has, for instance, imported several promising dwarfing stocks from Japan, with the aim of using these as future parents.

Despite the small scale of the current programme no additional funding is warranted for new apple rootstock breeding until the current Defra programme terminates. At that time (3 years hence) the situation should be reviewed.

Pear

New pear rootstocks have been produced over the last few years by Dr Kate Evans. Apparently, these crosses are currently funded under the same Defra programme mentioned above. The aim is the production of semi-dwarfing or dwarfing clones of *Pyrus communis* which are also capable of vegetative propagation. The screening of the rootstocks produced is conducted using Concorde as scion. Although this does not have the same merits, in terms of efficiency of land usage, as the use of columnars for apple screening, it should facilitate relatively rapid precocity of young trees.

This is a well-focused programme for the needs of pear producers in many regions of the world and is likely to be popular with the overseas licensees of the Apple and Pear Breeding Club. However, the chances of producing a very dwarfing or precocity-inducing rootstock clone of *Pyrus communis* are probably quite slim. If pear rootstock breeding is to continue at EMR and be focused more on the UK's needs, it would be appropriate to concentrate more on quince (only a few crosses are currently made) or on using other pear species. French research some years ago showed that seedlings derived from certain perry pears (e.g. the Brossier Series), which probably have *Pyrus nivalis* in their parentage, did have the capability of dwarfing pear scions significantly. Unfortunately, these promising rootstock clones proved almost impossible to propagate and have never been released commercially. Perhaps this avenue of breeding needs re-evaluation, with increased emphasis on ease of propagation.

Another promising avenue of research being pursued on a very small scale by Mr Tobutt is to produce bi-generic hybrids (either apple x pear or pear x quince) for use as pear rootstocks or interstocks. Production of such a hybrid, which had compatibility with both apples and pears could, theoretically, open up the possibility of grafting pear varieties onto the full dwarfing range of apple rootstocks. Mr Tobutt has already produced some of these hybrids but needs funding to further explore their potential as rootstocks/interstocks. This option is not as bizarre as it may at first seem; many years ago USA researchers showed that many pear varieties were graft compatible with the apple variety Winter Banana.

Sweet Cherry

There is no funding in place at EMR currently for the breeding of new rootstocks for sweet cherry. Nevertheless, Mr Tobutt has produced some interesting hybrids (*Prunus mugus* x *Prunus pseudocerasus*), which definitely warrant at least preliminary evaluation. *P. mugus* was shown many years ago to be capable of severely dwarfing sweet cherry scions, but its prostrate shrubby

habit made it very difficult to propagate. *P. pseudocerasus* is one of the parents of Colt, from which the latter derives its ease of propagation. Preliminary evaluation of these new hybrids using a sweet cherry scion indicates that they are compatible (at least in the short term) and dwarfing; moreover, tests show that they are also easy to propagate. It will be important to continue these evaluations to determine the effects of these hybrid rootstocks on scion cropping and fruit size. It is suggested that no further crosses are made until these hybrids have been fully evaluated. Thereafter, it would be useful to consider crossing the best of these hybrids, with a *P. cerasus* clone, such as Tabel or one of the Weiroot Series, or with *P. canescens*, if such crosses prove possible.

A hexaploid clone of Colt, produced by Professor David James and others, which provides vigour slightly (20%) less than Colt itself, may have value for small-fruited but abundantly cropping cultivars, such as Sweetheart. Hexaploid Colt is still not released to commerce. Although its use in the UK will perhaps be small it could generate revenue from royalties in countries such as Australia and New Zealand, where Colt is still very popular.

Plum

No breeding of plum rootstocks has been conducted at East Malling since Mr Richard Jones left the team some years ago. Plum rootstocks tend to have quite high ploidy levels and some of the most promising newer selections (e.g. Plumina) are quite complex hybrids. The EMR team are undoubtedly very capable of initiating a new plum breeding programme, but it would inevitably take some considerable time (and hence expense) to produce new fully dwarfing and fully graft compatible clones. It might be better to try and gains access to discarded seedlings with dwarfing potential from the several plum breeding programmes in progress abroad. Plums are, in most countries, grown as prunes on standard trees suitable for mechanical harvesting. This system of culture has little interest in very dwarfing selections.

Scope, appropriateness and efficiency of the orchard evaluation and development of new rootstocks in the UK

The orchard evaluation of new rootstocks, which is currently based mostly at EMR, falls into three categories:

1. Screening rootstocks bred by EMR breeding team (mainly apple and pear rootstocks but also a few cherry rootstocks).
2. Evaluation of the most promising rootstocks for apple, pear, sweet cherry and plum, which have been produced by breeders elsewhere in the world.
3. Monitoring orchard trials of new rootstocks established on grower farms in the UK.

Funding and responsibilities

The first of these categories (1 above) is funded as part of the Apple and Pear Breeding Club (of which HDC is a partner). The other two categories, (2 and 3), rely on funding from HDC for their support. Currently there is no HDC or other funding to EMR for the evaluation of rootstocks for sweet cherry or plum.

Up until the current time, the screening trials (1) of apple and pear rootstocks were planted with Queen Cox, Gala, Fiesta, Conference or Comice scions and the evaluations conducted by members of the Pomology team. In future, this first stage screening may be conducted by the breeders themselves using columnar apple or Concorde pear scions. It is suggested that it would be better if

there were to be collaboration between the two teams in this future screening. All of the evaluations conducted on foreign rootstocks and on grower farms is conducted by Dr David Johnson and Ms Jane Spencer (i.e. the Pomologists).

Range and appropriateness of choice of the rootstocks evaluated and grubbing of existing trial

The EMR-bred rootstocks planted in orchard screening trials are selected by the EMR breeders. This should continue in the future but the breeders should be asked to take account of the priorities determined by this study.

The choices concerning which of the foreign-bred rootstock selections to plant in EMR trials have traditionally been made by the Pomology team. It seems sensible to continue this tradition, although they need to take account of the UK's priority rootstock objectives and may also require some guidance as to the promising materials available worldwide. The range of foreign rootstocks planted in current trials and those conducted over the last 10-15 years appears to be largely appropriate.

There is an urgent need for funding of evaluation trials of plum and sweet cherry rootstocks. One international trial of cherry rootstocks is currently planted at EMR and is partly managed by the Cherry Club. A trial of promising plum rootstocks is planted on a grower's farm in East Kent. Both trials need funding. New international trials of plum and cherry rootstocks are being planned in the Netherlands; the UK should be a partner in any such future initiative.

Sufficient information has been gathered on several of the existing HDC-funded EMR trials of rootstocks (e.g. trials of USA- and Canadian-bred apple rootstocks and one trial of EMH quince rootstock); these should be grubbed this spring, so as to free up resources to focus on other newer trials. One screening trial of apple rootstocks (WE 183) should also be grubbed, with the approval of the Apple and Pear Breeding Club.

Efficiency of the evaluation procedures

Up until approximately 5 years ago it could be argued that some of the records taken on the EMR rootstocks trials (e.g. annual shoot length) were somewhat superfluous. These have been rationalized in recent years and the range of records now taken strikes about the right balance, taking account of the need to provide HDC with annual reports on the various trials. The costs of the various orchard trials are expensive but these are not determined by the pomology team but by accountants and senior management at EMR.

Efficiency of technology transfer of rootstock evaluations

The technology transfer of the results from rootstock trials conducted in the past, as measured by the uptake of promising new rootstocks, has not proved very efficient. This is despite numerous EMRA Members' Day presentations, articles in the commercial press and several papers published in scientific journals. This shortcoming needs urgent attention.

The authors speculate that there are a number of reasons for this failure:

- Satisfaction with existing rootstocks for apple and pear.
- Growers not attending EMRA members Days.

- Growers relying entirely for their information from commercial advisory services which also often fail to attend Members Days and have a vested interest in presenting new information as exclusive to themselves.
- UK nurserymen failing to take up new rootstocks in the absence of any guaranteed sales.

HDC, EMR and the commercial advisory services need to discuss how these problems can be overcome to the mutual benefit of all concerned.

One strategy would be to organise plantings of the most promising rootstocks on grower farms. However, experience suggests that these are a poor source of reliable information and can often be exclusive to particular advisory organisations.

A further suggestion is that HDC organise the production of Rootstock Fact Sheets on each of the main fruit crops.

Evaluation of new rootstocks on commercial grower holdings in the UK

Very few grower trial sites are currently in existence. Only a few trials of the new EMR quince rootstock, EMH, are planted and not all of these are recorded. Despite the problems highlighted, above technology transfer would be improved by expansion of this part of the evaluation process. It is suggested that some consideration be given to providing growers with some form of remuneration for hosting trials in return for which there should be contractual commitments aimed at guaranteeing no loss of required records (e.g. as often happens with premature picking of plots).

Rootstocks which have shown promise in similar trials conducted abroad should move directly into grower trials, providing the required protection under patents or PVR can be assured. Such trials should either be in parallel with a trial with the same selections based at EMR on which more detailed records are taken, or even in the absence of the more detailed trial where this is not thought to be necessary. A member of EMR staff should be involved in monitoring these grower trials.

Collaboration with similar rootstock evaluation programmes based abroad

Discussions should be held with scientists and others in charge of rootstock evaluation programmes in countries such as Netherlands, Belgium and Germany, with a view to sharing of trial results. This may save on resources and avoid unnecessary overlap. Where collaborative trials are planted within Europe, that include rootstocks of potential interest to the UK, every effort should be made to join in these programmes. Currently, an approach has been made asking the UK to collaborate in a new international plum rootstock trial. It would be worthwhile to make funding available to facilitate the UK’s participation in this trial.

Conclusions

New and improved rootstocks will be essential to a sustainable future for UK tree fruit production in an era of intense global competition and potential climate change. There is a strong need for rootstocks for apples, pears, plums and cherries that are dwarfing, precocious, high yielding and offer some measure of drought tolerance.

UK trialling of promising UK and overseas material should continue. It is essential that growers have access to information on the performance of rootstocks under UK conditions before they need to make long term investment decisions.

It is essential that strong links are maintained with holders of genetic resources for tree fruit, in particular the collections held by USDA germplasm repositories and the Genebank at Dresden, Germany in conjunction with the Defra National Fruit Collections. This will be important in order to seek to ensure access to dwarfing genes and genes controlling root function.

During the review it became apparent that there is an acute risk that the propagation skills and knowledge necessary to support a rootstock breeding and introduction programme might be lost in the next few years. Many of the novel and unusual techniques which have been used to propagate, particularly those rootstocks which prove difficult by standard commercial means, could be lost as staff retire or move to other opportunities. It is strongly recommended therefore that HDC commission the creation of a propagation manual to capture these techniques for potential future use. A manual of this type would provide essential backup to any work on rootstocks and might also be of interest to hardy nursery stock growers who can encounter similar problems when propagating other woody plants.

There is also concern relating to plant health aspects of a rootstock programme and in particular the need for virus indexing, the creation of virus tested/virus free stock and the EMLA scheme.

Technology transfer should be improved. There is a substantial amount of information available from work in UK and overseas that would benefit growers enormously when they need to make key investment decisions on rootstocks, many of which are available from European nurseries.

A more proactive approach to the commercialisation of new rootstocks should be encouraged within the APBC. It may be expedient to endeavour to convince the APBC that more of its funding should be diverted to rootstock breeding rather than scion breeding.

General recommendations

- HDC should encourage the full interaction of breeders with the relevant genebanks and between genebanks.

- HDC should discuss with EMR the methodology to be employed in bulking up rootstocks for grower trials and subsequent commercialisation.

- Clear thought, by HDC in discussion with Defra and EMR, should be given to the plant health implications of new introductions and in particular the need for appropriate virus indexing and associated measures.

Apple rootstocks

- A rootstock is needed with vigour intermediate between M27 and M9, which performs well in the nursery and which produces precocious and consistently abundant yields of high quality fruits of the marketable size grades.

- A replacement rootstock is needed in the M26 vigour category, which does not suffer from burr knotting, poor calcium uptake or physiological disorders. This rootstock should also induce precocious and abundant yields of high quality fruits.

- In the medium term dwarfing rootstocks will be needed which can tolerate drought and weed competition better than the existing dwarfing rootstocks.

- In the long term climate change may bring a need for apple rootstocks that are tolerant or resistant to fireblight.

Breeding and initial screening of new apple rootstocks by EMR

- Currently, all of the funding for making new crosses of apple rootstocks is derived from a Defra-funded project on Marker Assisted Selection. The crosses made as part of this project are appropriate for the project's aims and may provide some useful rootstocks as a spin-off for subsequent evaluation as part of the Apple and Pear Breeding Club (of which HDC is part contributor), or for the HDC in its own individual rootstock evaluation project.

- New apple rootstock crosses have been made in each of the last four years and some of those produced have already been budded with a scion. The first crops on this new wave of rootstocks should be harvested in 2005. A technique to aid rapid evaluation of new rootstocks has been developed, which is to be commended, involving the use of columnar scions and minimal land.

- No additional HDC funding is warranted in this area currently. The situation should be reviewed in three year's time, when the Defra project terminates.

Apple rootstock orchard evaluation by EMR and growers

- One new rootstock selection M116 has been released recently from the EMR programme. This is a rootstock with similar properties to MM106 but with very strong resistance to collar rot. This would make an ideal rootstock for cider apple production.

- Almost 100 selections emerging from the first preliminary screen at EMR have been adequately field tested in preliminary orchard trials based at East Malling. Approximately 10 promising rootstocks (with vigour ranging from M27 to M26) have been selected to date from these trials. Serious delays have then followed these initial trials when attempts have been made to bulk up the promising selections for larger scale trials on grower holdings.

- In the past field evaluation of a range of Polish, Czech, Russian, German, American, Canadian and Swedish apple rootstocks has taken place at EMR Some showed promise and possibly warrant further evaluation by UK growers. Trials on several USA and Canadian rootstocks continue at EMR. Several of the American (Geneva) selections show potential.

- A limited number of new selections from abroad should be imported for testing in the UK. These should be chosen mainly from the new rootstocks developed in Poland, Japan and the USA and should focus on the clones likely to fulfill the UK objectives listed above. Consideration should be given to expanding testing of new promising foreign apple rootstocks to cover several grower sites, as well as a trial based at EMR.

- The records and measurements made by the EMR team on the various orchard trials appear to be largely in line with the requirements of the industry. Records of shoot growth have sensibly been abandoned, having been deemed to be too labour intensive. This is a sensible approach. In future apple rootstock trials scions such as Gala and Braeburn should be considered for inclusion in rootstock trials as well as Queen Cox and Bramley's Seedling where funding allows.

Apple recommendations

- No additional HDC funding is warranted for breeding at this time. The situation should be reviewed in three year's time, when the Defra project terminates.

- Changes that have been put in place for streamlining both breeding and field selection at EMR are to be welcomed.

- The serious delays that have occurred over recent years when attempts have been made to bulk up the promising selections for larger scale trials on grower holdings should not be allowed to happen again. It is wasteful of resources and delays growers from gaining access to potentially useful rootstocks. HDC should actively work with EMR and the APBC to ensure a system is in place that can generate plants for trial and commercialisation efficiently.

- The commercialisation of rootstocks generated from EMR and channelled through the APBC has the potential to return a useful revenue stream to HDC and EMR. HDC should seek to encourage the APBC to refocus more on rootstocks and move slightly away from an over concentration of effort on scion cultivars.

HDC trials should consider inclusion of the following:

Breeding Programme	**Rootstock Clone(s)**	**Attributes of clone**	**Trials suggested**	
			EM trial	**Grower trial**
EM, UK	**M116 (AR86.1.25)**	MM106 vigour and yield performance but very resistant to collar/crown rots. Possible for cider?	Already completed tests	Yes
	AR 801.11	M26 vigour but better productivity	Screening trial completed; new trial planted	Yes
	AR 680.2	M9 vigour or slightly less; but better productivity	Yes	Yes
	AR295.6	Vigour slightly less than M9; good yield efficiency	Already in second stage trial at EM	Yes
	AR.852.3	Vigour < M9 but > M27 good	Possibly – only	Possibly

		yield efficiency	screening trial to date	
	AR 69.7	Vigour similar to M27	No further test warranted at EM	Yes on good site possibly for Bramley
	AR628.2	Vigour similar to M27	No further test warranted at EM	Yes on good site possibly for Bramley
	AR672.1	Vigour slightly more than M27 and better fruit size	No further test warranted at EM	Yes
	M.20	Vigour similar to M27 but better fruit size	No further test warranted at EM	Yes
Poland	**P22**	Vigour < M9 but on good soils > M27	Tests already completed	Yes
Czech Republik	**J-TE-E**	Vigour less than M9 but greater than M27 and good yield efficiency and fruit size	Already completed tests	Yes
	J-TE-G	Vigour slightly greater than M27; performs ell with Jonagold in Belgium	No	Yes
Germany	**Jork 9**	Vigour between M26 and M9; better yield efficiency and tolerates drought and weed competition well – suitable for organic systems?	Already completed tests	Yes
USA	**G 41**	Vigour slightly less than M9; performing well in European trials	Yes*	Possibly

Pear Rootstocks

- There is a need for increased dwarfing of pear scions to fit them to high-density systems without the need to resort to the use of either plant growth regulating chemicals or root pruning.

- Whilst dwarfing quince stocks are the best way forward for scions such as Conference and Comice, most new pear varieties are incompatible with quinces and need the use of expensive interstocks. A fully dwarfing and easy to propagate *Pyrus* stock would be beneficial to give a much wider range of graft compatibility with new pear varieties, as well as providing better tolerance of drought and alkaline soils.

- New dwarfing rootstocks that improve pear precocity of cropping are vital if pears are to remain economically viable.

Breeding and initial screening of new pear rootstocks by EMR

- Currently any crossing of pear rootstocks that is undertaken is funded by the Defra project, although some crosses were made prior to this project and were funded as part of the APBC

project. Most of the crosses made have been of *Pyrus* but some quince crosses have also been included.

- The crosses made as part of this project are appropriate for the project's aims and may provide some useful rootstocks, as a spin-off for subsequent evaluation as part of the Apple and Pear Breeding Club or the HDC in its own individual rootstock evaluation project. Attempts are being made to speed up the evaluation of the new rootstocks produced by budding with Concorde, which we support.

- No additional funding is warranted in this area currently. The situation should be reviewed in three year's time, when the Defra project terminates.

- It would be expedient to endeavour to convince the APBC that more of its funding should be diverted to rootstock breeding rather than scion breeding

- Some interesting crosses between *Malus* and *Pyrus* and between *Pyrus* and *Cydonia* (quince) to produce bi-generic hybrids have been carried out at EMR. Theoretically, these could provide compatible bridge grafts between pear scion varieties and the whole range of fully dwarfing apple rootstocks. This work is speculative but could be valuable and ways of funding this should be sought although we do not believe HDC alone should support this.

Pear rootstock orchard evaluation by the EMR team and growers

- One new quince rootstock, the dwarfing EMH (previously QR196-16), has been released from the EMR programme. Although inducing poorer precocity than Quince C, EMH is of value in inducing larger fruit size. Trials of EMH on grower sites are also being evaluated.

- Currently, there are several trials in the ground at EMR evaluating EMR selections of *Pyrus* clonal rootstocks. These trials are funded by the APBC programme. Very few quince clones are currently in these trials, although one EMR quince selection C132 shows promise in UK and Dutch trials as being slightly more dwarfing than Quince C. C132 should be bulked up for further testing on grower sites and possible release.

- Most of the *Pyrus* rootstock selections are inducing intermediate vigour and are not of significant relevance to UK grower needs. Only one stock QR708-36 shows preliminary promise in inducing good crops on trees of medium size.

- From HDC's viewpoint the trials of most of these *Pyrus* clones are of very low priority. The APBC's goals are different and may warrant continued testing of some of these selections.

- The EMR team is also evaluating, under HDC funding, *Pyrus* and quince rootstocks imported from other breeding programmes abroad. Several of these trials were begun in collaboration with Dutch researchers.

- Trials testing the much publicised German *Pyrus* rootstock Pyrodwarf have shown it to be invigorating and of very poor performance. Although delivering negative results, the trial has served a useful purpose in warning UK growers not to plant this stock.

- The future HDC funded pear rootstock should focus on seeking UK and foreign stocks that meet the UK's specific goals. More emphasis on dwarfing quinces is warranted, with HDC funding trials of C132 on grower farms

Pear recommendations

- No additional HDC funding is warranted for pear breeding at this time. The situation should be reviewed in three year's time, when the Defra project terminates. If pear rootstock breeding is funded by HDC in the future it is suggested that greater emphasis be placed on breeding new quince rootstocks.

- HDC should endeavour to convince the APBC that more of its funding should be diverted to rootstock breeding rather than scion breeding

- HDC should encourage (but not fund directly) investigations to produce bi-generic hybrids of *Malus* and *Pyrus* and between *Pyrus* and *Cydonia* (quince). This speculative work could produce a valuable step in crop production but is too "risky" at this time for HDC funding alone.

- HDC should consider funding grower trials of the rootstocks, C132 and QR708-36 as soon as possible.

- C132 should be bulked up for potential commercialisation.

Sweet cherry rootstocks

- The main requirement is for a rootstock that is more dwarfing than either GiSela 5 or Tabel and would control the vigour of trees sufficiently for easy growth within tunnels.

- Dwarfing stocks that are easier to propagate than either Tabel or GiSela are also needed. This should facilitate the production of less expensive trees.

- More minor requirements are for dwarfing rootstocks that are more suited to heavy clay soils (GiSela clones perform poorly in wet soils) and for dwarfing stocks that induce large fruit size.

Breeding and initial screening of new sweet cherry rootstocks by EMR

- There is no current funding from any source for breeding of sweet cherry rootstocks. It is difficult to justify the level of investment needed to restart a programme given the present size of the UK cherry industry. However, if funds did become available crosses involving Gisela and Tabel would be potentially interesting.

- Some crossing in recent years has been carried out at EMR between the very dwarfing rootstock *Prunus mugus* and *P. pseudocerasus*, which is a parent of Colt. The aim was to produce fully dwarfing stocks, which were easy to propagate. Preliminary evaluation of the resulting hybrids indicates the production of hybrid stocks that are easy to propagate and also dwarfing. This work might be capable of development as part of PhD work.

- It is suggested that a small evaluation trial of these hybrids may provide valuable results at relatively little cost. HDC should consider limited funding for such a trial. No other HDC work is therefore suggested in this area.

Sweet cherry rootstock orchard evaluation at EMR and by growers

- There is only a very minimal amount of funding for sweet cherry rootstock field evaluations. This is provided by the Cherry Club. The trial is comparing most of the most promising dwarfing rootstock selections from breeding programmes abroad. However, the records currently taken on this trial are minimal. It is one of several trials, all with the same rootstocks and scions, which were planted as part of an international collaboration. HDC should support the continuation of this trial and facilitate the UK's collaboration in any future international sweet cherry rootstock trialling initiative. Such international co-operation enables greater levels of information to be generated for the benefit of growers in a shorter time than would be affordable for UK "stand alone" trials.

- EMR are endeavouring to obtain trees on a new GiSela selection, GiSela 3, which is reported to be more dwarfing than GiSela 5 or 6. HDC funding to aid the testing of this stock by the industry (recorded by EMR staff) under commercial polythene tunnels is recommended.

Cherry recommendations

- HDC should not fund work in cherry breeding at this time but should be ready to aid the orchard screening of advanced selections.

- HDC should support the International Rootstock Trial and encourage EMR to participate in such future trials, providing funds where possible.

- HDC should discuss the possibility of limited funding to evaluate promising progeny from *P. mugus x P. psuedocerasus* crosses.

- HDC should fund grower trials of hexaploid Colt, with appropriate varieties and Gisela 3, under tunnels.

- HDC should encourage EMR to commercialise hexaploid Colt.

Plum rootstocks

- Rootstocks are required which provide increased dwarfing for plum trees to facilitate production under fully high-density systems.

- Rootstocks that induce precocious and consistently abundant yields of large good quality fruits are essential.

Breeding and initial screening of new plum rootstocks by EMR

- There is currently no breeding of plum rootstocks funded at EMR, but EMR staff have the expertise to do this should it be required. A few clones generated as part of an earlier plum

scion breeding programme terminated some years ago, may have potential as dwarfing rootstocks.

- New plum rootstock breeding does not command high priority currently, therefore no HDC funding is recommended in this area but this situation should be reviewed in 5 years time.

Plum rootstock orchard evaluation at EMR and by growers

- No trials of plum rootstocks are planted at EMR. EMR staff members are however, asked to monitor one trial planted on an East Kent farm. This trial includes a stock generated in the Crimea region of Russia, named VVA1. This is proving a very promising stock in Dutch and other trials.

- A small amount of additional HDC funding is warranted to facilitate the recording of this trial and possibly the residual clones from the breeding programme.

- Trials conducted some years ago at EMR, in collaboration with Dutch researchers showed the considerable merits of Plumina as a replacement for Pixy and Ishtara as a replacement for St. Julien A. Both stocks induce larger fruit size than the standards. Renewed attempts to reiterate this message may be warranted. Consideration should be given to facilitating a demonstration planting of Plumina and Ishtara worked with Victoria, Marjories Seedling, Jubelum and Reeves Seedling.

Plum Recommendations

- New plum rootstock breeding does not command high priority at present, therefore no HDC funding is recommended in this area but this situation should be reviewed in 5 years time.

- HDC should fund a grower trial of Plumina, Ishtara and VVA-1 as soon as possible.

Technology transfer

The flow of information from rootstock research and development to growers over recent years has not been good. Principally, this situation has occurred because of uncertainty over work programmes, changes to staffing/work in response to financial pressures and poor liaison/collaboration between the scientists and the advisors. Over this time, information has been built up but not been promulgated to the industry. It is strongly recommended that information from work in the recent past should be made available to growers as soon as possible. There is an immediate need for six HDC factsheets;

1. **Apple rootstocks** – which would bring together information from UK and overseas sources on the rootstocks that are currently available, highlighting their attributes. The aim would be to aid and improve grower's decision making.

2. **Pear rootstocks** – which would bring together information from UK and overseas sources on the rootstocks that are currently available, highlighting their attributes. The aim would be to aid and improve grower's decision making.

3. **Plum rootstocks** – which would bring together information from UK and overseas sources on the rootstocks that are currently available, highlighting their attributes. The aim would be to aid and improve grower's decision making. Trials conducted some years ago at EMR, in collaboration with Dutch researchers showed the considerable merits of Plumina as a replacement for Pixy and Ishtara as a replacement for St. Julien A. These rootstocks would form the basis for this factsheet.

4. **Cherry rootstocks** – which would bring together information from UK and overseas sources on the rootstocks that are currently available, highlighting their attributes. The aim would be to aid and inform grower's decision making.

5. **Apple Rootstock M116** – Factsheet to highlight available knowledge. Much of this information has already been collated but would benefit from being published in HDC Factsheet format.

6. **Pear Rootstock EMH** (OR196-16) - Factsheet to highlight available knowledge. Much of this information has already been collated but would benefit from being published in HDC Factsheet format.

In addition it is suggested that a Rootstock Seminar be held for growers and their advisors in the winter period to present results of work and launch the factsheets.

It is strongly recommended that HDC commission the creation of a propagation manual to capture novel and unusual techniques of propagating rootstocks which may prove difficult by more conventional means. A manual of this type would provide essential backup to any work on rootstocks and might also prove to be of interest to hardy nursery stock growers who might encounter similar problems when propagating woody plants.

Glossary

APBC Apple and Pear Breeding Club. Consortium of HDC together with European nurseries that provides funding to the breeding programme at East Malling Research.

EMR East Malling Research.The main research contractor to Defra and HDC on fruit crop science, genetics and breeding.

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APPENDICES

Appendix 1

HDC STRATEGIC REVIEW OF ROOTSTOCK BREEDING & TRIALLING

MEETING HELD ON 11 NOVEMBER 2004 AT INVICTA INNOVATIONS, EMR

1 Present and apologies

Present	**Apologies**
P Barwick	C Baxter
T Biddlecombe	A Boxall
C Chandler	D Budd
J Simpson	N Dunn (Nick's comments tabled)
A Tinsley	B Piper
T Webster	C Rook
	W Sibley
	D Vaughan

2. Objectives
Objectives *of* the review

i) To evaluate the effectiveness of the current HDC projects;
ii) To identify the current and likely future rootstock requirements of the UK tree fruit industry (apples, pears, plums and cherries); and
iii) To make recommendations for future investment in the breeding and development of rootstocks under the HDC research and development programme.

Specific objectives *of* the meeting

To address objective ii) above.

3 Research and funding priority

The meeting agreed that rootstock breeding and trialling was critical and fundamental and of a higher priority than scion breeding and trialling. The latter was increasingly being undertaken by marketing groups and leading growers.

4 Problems with existing rootstocks

The following problems were highlighted for rootstocks of apple, pear, plum and cherry:

Ease of nursery production, maiden quality, tree size, anchorage, support requirement, growing period, harvest timing, pest and disease tolerance, drought/weed tolerance, water-logging tolerance, yield, fruit quality, precosity, consistent performance, nutrient uptake and storage potential.

In addition incompatibility was noted as a problem for pears and cherries. The tendency towards flower/fruit bunching of cherries on some rootstocks can lead to both small fruit and to disease. Root sucker production was noted as a problem on plums.

5 Urgent requirements for new rootstocks

Apple

Due to the increasing shortage of skilled labour there is an urgent need for a rootstock between M27 and M9 in vigour rapidly reaching 2m tall but no higher. The wide range of currently available dwarfing rootstocks need to be evaluated in the UK.

Due to the constraints of climate change, water use restrictions, the potential loss of some herbicides and the increase in demand for organic produce there is a need for drought weed tolerant rootstocks albeit perhaps in the slightly long term

With the potential development of commercial columnar scion varieties and increased mechanisation of orchard operations (harvest?) in the longer term, there would be a need for a suitable easily propagated well-anchored dwarfing or semi-dwarfing rootstock.

Improvements to abiotic and biotic resistance are a priority.

Self-thinning would be a valuable attribute to ensure consistent high yields of market quality

Pear

The major problems of compatibility, precosity, yield, fruit size and consistent cropping must be addressed. The French pear variety Paradelle is being trialled as an easily rooted dwarfing rootstock in Europe and should be assessed in the UK.

Plum

The lack of a reliable dwarfing rootstock must be addressed. This appears not to be regarded as an important objective in international breeding programmes and much material with dwarfing potential is discarded overseas. Breeders should be asked to send such material to the UK for trialling in future.

Cherry

Although greater attention has been devoted to breeding dwarfing cherry rootstocks internationally there remains a requirement for smaller trees suitable for growing under covers (e.g. Gisele 3).

6. Future trialling

International collaboration and trialling must be encouraged, particularly within Europe.

More use should be made of newer commercial varieties (Gala, Braebum) in rootstock trials.

Problems with bulking up tree numbers of interesting selections for trials must be addressed.

Industry trials should be part of a collaborative unified approach involving growers and consultants as well as researchers.

Trials undertaken at EMIR should be managed in line with commercial practise and be undertaken on commercial holdings as early as possible.

7 Other comments

UK rootstock breeding appears to be under-funded and at a low ebb currently. A long-term strategy with guaranteed funding at appropriate levels is required.

The lack of a fully functioning virology department at EMR is of concern.

Indexing and heat therapy are urgently required to ensure that parent stock remains of high health status.

The EMLA scheme appears top be in rapid decline