EXECUTIVE SUMMARY (MAFF: OF0150)

REASONS FOR STUDY AND KEY OBJECTIVES. There is a strong demand for organic fruit in the UK but the majority of this is met by imports. The main constraint on home production is a shortage of growers with sufficient acreage to supply wholesalers and supermarkets. The Organic Fruit Focus Group identified lack of technical information and research as a major barrier to growers considering conversion. The main aim of the present study was to gather technical information on organic growing techniques from growers, advisors and researchers from both the UK and abroad. Research priorities were also identified. Crops reviewed were apples, pears, strawberries, currants, gooseberries and raspberries.

MAIN FINDINGS.

- **Research review.** The most information was found on organic apple and strawberry production. Much of it was obtained by contacting researchers and advisors and is unrefereed literature e.g. conference proceedings, annual reports, advisory booklets and press articles. Relevant research from conventional systems was also reviewed.
- **Advisory literature from abroad.** The most useful literature was from FiBL in Switzerland, LBI in the Netherlands and The Danish Agricultural Advisory Centre.
- **Research and development programmes abroad** are producing relevant information of immediate use to UK growers.
- **Drafts of two booklets** have been written during the review by combining several sources of information, i.e. 'Organic apples - pest and disease management' and 'Organic strawberry production - a growers guide' (see appendix 2 & 3)
- **Apples and pears.** Technical problems are numerous but organic apple production can be profitable mainly because there is a market for organic class II fruit. However the conversion period is a major financial and technical barrier. Research priorities were identified, these included a) variety trials, b) scab control, c) studies on weed control/water/nutrients e.g. management of the orchard alleyways and the tree strip to encourage beneficial insects, manipulate nutrient supply and provide orchard access d) pest control e.g. optimising the use of floral strips to prevent pest epidemics and specific control methods for numerous major pests.
- **Strawberries.** These are considered easier to grow. Suitable systems for weed control have been developed. The main problems and research priorities are a) *Botrytis*, b) powdery mildew, c) soil borne diseases (*Verticillium* and *Phytophthora*), d) encouraging beneficials for pest control e) optimising nutrient supply.
- **Raspberries, blackcurrants and gooseberries.** Few growers with reasonable acreage were identified making it difficult to draw comprehensive conclusions. However, weed control is a major problem. Research priorities include management of the crop pathways and optimising the use of mulches. An important pest is raspberry beetle. Various other pests could become a problem if acreage is increased.

TECHNOLOGY TRANSFER. Four possible avenues of dissemination were identified.

- Collaboration with FiBL in Switzerland to produce adapted translations of grower booklets
- Production of booklets through the Soil Association's Technical Guides for Organic Food Production
- More immediate dissemination of 'less glossy' leaflets through the Organic Fruit Focus Group
- Seminar/workshop/farm walk collaborative events between HDRA, Soil Association, Elm Farm Research Centre, Organic Fruit Focus Group and East Malling Research Association. Two events are already planned.

ISSUES RELATED TO POLICY, ORGANIC STANDARDS AND PESTICIDE REGISTRATION

a)The three year conversion period, in both top fruit and cane and bush fruit, is a major financial barrier. b) The unpredictable nature of fruit production may mean that financial support after conversion could be required to increase grower confidence. c) Diversification of business enterprise for top fruit could be encouraged. d) Long term and achievable standards of fruit quality should be agreed between supermarkets and growers. e) Products which could be important for organic fruit production were identified for consideration by PSD and/or UKROFS. f) Strategies for the propagation of organic plants for all fruit crops need to be developed; this could be done within a European context for some crops where there are no licensed propagators in the UK. g) Some tentative evidence suggests that the measures used to encourage beneficial fauna for pest control in organic orchards and the absence of soil sterilants in organic soft fruit production are resulting in species diversification; this needs to be explored further.

SCIENTIFIC REPORT

Despite a very strong consumer demand for organic fruit it is the least developed sector of the UK organic industry. The main constraint to growth is a lack of organic fruit growers, especially those on a large enough scale to supply the wholesale, supermarket and processing markets. The UK Organic Fruit Focus Group was set up in 1997 as a producer initiative to develop the market and production of UK organic fruit. At the first meeting of the group it was concluded that a) the absence of written technical information on how to grow organic fruit b) the lack of experienced advisors c) a lack of research on fruit and d) a lack of information on the economics of organic fruit were major barriers to grower confidence and hence expanding production.

The main aim of this project was to collect information on organic fruit production from growers, researchers and advisors from the UK and abroad. Then to evaluate this information and provide it in a form which could be used as the basis for technical guidelines. The identification of research needs was also an important priority.

Fruit crops covered by the review were apples, pears, strawberries, raspberries, currants and gooseberries.

1. SCIENTIFIC OBJECTIVES

1. To identify and review current methods of organic top and soft fruit production in the UK and to identify the major technical problems, or other factors, limiting production.
2. To review the existing knowledge of fruit production (published literature and on-going research) focusing specifically on issues of relevance to organic production.
3. To collect and review information on best practice in other countries (primarily countries in the EU). Aiming particularly to identify how the technical problems, which are currently encountered in the UK, are dealt with elsewhere.
4. To evaluate the above information with the aim of producing technical recommendations and advice on organic fruit production. It is envisaged that this will form the basis of information for a series of best practice guidelines for production of apples, pears, strawberries, raspberries, currants and gooseberries.
5. To identify priority areas for research and development.
6. To investigate and make recommendations on appropriate methods for technology transfer to a wide audience base.

The primary milestones were:
1. To identify current practice and production problems.
2. Carry out library and data base searches.
3. Evaluate existing information for relevance to organic UK production.
4. Prepare report including technical recommendations.

2. METHODS AND APPROACH

The review was initiated by consultation with the industry. This included visits or direct contact with over 20 top or soft fruit growers from the UK and 5 from Switzerland and the Netherlands. Many more were approached indirectly through meetings, open days and workshops. Other representatives of the industry were also consulted and included packers, processors, retailers and cider producers.

Visits were made to organic research institutes in the Netherlands and Switzerland. Other researchers and advisors were contacted in areas of Europe and the rest of the world that had reasonably similar climates and consequently similar pest and disease problems as in the UK. Useful responses were received from Sweden, Denmark, New Zealand and the U.S.A. Unfortunately, there were no responses from France, Belgium or Germany.

Literature searches using data bases, the internet, traditional library searches and press searches were carried out. Researchers and advisors involved in both conventional and organic production in the UK were also contacted or visited.

3. EXTENT TO WHICH OBJECTIVES WERE MET

It was relatively easy to find information on organic apples (desert and culinary) and strawberry production. It is felt that they are well covered by the review. Consequently drafts of two booklets for growers have been produced on apples and strawberries (See appendices 2 &3). However, very little written information was found on organic cider.

Far less information was found on the other crops. Pears are not nearly as well represented as apples in advisory information or research puplications. It is often assumed that pears suffer from the same problems as apples and are grown in a similar way. Some aspects of raspberry production and blackcurrant production are covered. Apart from some advisory information from Switzerland nothing was specifically found on organic gooseberries. Also it is a relatively minor crop and is not the subject of much conventional research.

The lack of response from German contacts is possibly of most concern as it is felt that there is likely to be some research and information there and that this would have helped address the balance on the lack of information on cane and bush fruit. However, literature searches were not successful either. It is hoped that contact will be made eventually, and that if it is worthwhile, a study tour to Germany, Denmark and Sweden could be made which will concentrate on organic soft fruit. There are also some research programmes on soft fruit in Norway and Finland which may be worth further investigation.

4. MAIN CONCLUSIONS AND FINDINGS (APPLES AND PEARS)

4.1. NATURE OF THE INDUSTRY

The nature and size of organic enterprises and their market outlets are diverse, ranging from a small number of relatively large orchards (approx. twelve) where top fruit is the main enterprise, to numerous small orchards of less than half an acre. The importance of the small orchards to the overall organic market and their technical needs should not be overlooked. All sectors of the market are represented to some degree i.e. direct marketing, wholesale, supermarket, processing, juicing, cider and perry.

4.2. FINANCIAL VIABILITY

Organic dessert and culinary top fruit can be viable in the UK despite the generally lower yields (50% to 80%) than those achieved in conventional production. This is because there is a market for organic grade II fruit and for juicing and processing. Organic top fruit production is fraught with many technical difficulties and can be a high risk operation. In response to this some growers diversified into new businesses or have added a complementary farming enterprise. Some have made sure that they get a reasonable return from any fruit rejected by the market by processing it themselves or by direct marketing.

4.3. DIFFICULTIES DURING CONVERSION

The conversion period can bring major financial difficulty. The growers still have to bear the costs of running or establishing an orchard but any fruit has to be sold as conventional. Often yields are reduced while the orchard and grower adapt to new growing techniques. Much of the fruit only reaches the conventional grade II standard for which there is virtually no market.

The solution is that growers are given greater financial support during this time, the market for 'in-conversion fruit' is developed further and that there is more research and development input for this period.

4.4. SUPERMARKET QUALITY STANDARDS

Organic growers have experienced problems with their fruit not reaching the high standards expected from the supermarkets. Supermarkets are more sympathetic towards allowing a lower cosmetic appearance in organic fruit but growers still fear that standards will become more stringent once they have started to supply. It is important that realistic standards are set which are both acceptable to consumers and

achievable using organic growing methods. Major characteristics to consider are fruit size, pest and disease blemishes, russetting and firmness. Different varieties may need different standards. Ideally this standard should be set for a number of years so that every one concerned knows the target.

If sensible standards are not adopted this could seriously restrict the growth of the industry. Growers considering conversion see it as yet another difficulty and if their fears are realised they either go out of business or adopt other marketing strategies. If the reduction of imports is a genuine goal then this is most likely to be achieved through increased UK production for the supermarket trade.

4.5. PESTICIDE REGISTRATION AND ORGANIC STANDARDS ISSUES

It is highly likely that in the near future there will be more pest control products available that use pheromones for mating disruption or for increasing the efficiency of traps to achieve pest control. According to UKROFS pheromones are permitted as an insecticide and as an attractant for use in traps and dispensers. It is unclear as to whether mating disruption is included. Soil Association standards permit pheromone traps for monitoring purposes only and do not mention their use in traps for achieving control or for mating disruption. Sticky fly traps without insecticides are permitted. The application of pheromones could make them more specific than coloured traps and help reduce the number of beneficials caught. Issues of whether the use of pheromones for these purposes adhere to organic philosophy are being considered by the Soil Association. However, these products also need to be considered by PSD before they can be used in the UK.

Products based on acidic clay minerals e.g. bentonite clay and products such as Ullmasud, MycoSin and MycoSan may need to be considered by PSD and UKROFS for scab control. They are not as effective as copper compounds but are less damaging to natural fauna and appear to be the most likely candidates for the replacement of pre-flowering copper compound sprays for scab.

Other products requiring consideration by PSD are granulosis virus, Quassia and possibly pyrethrum and neem. See section 4.9.

There are also the issues and implications of having to use organically propagated trees in the year 2001. At present organically raised trees are not available so growers are planting conventionaly propagated trees and then converting them to organic production.

It would be useful to consider whether the three year conversion period for perennial crops could be reduced to two years. This would significantly reduce the length of time growers have to withstand negative cash flow during the conversion period. The three year conversion period for perennial crops is currently an EU ruling but circumstances and the use of persistent chemicals in conventional production may now have changed. This needs further investigation.

4.6. TECHNICAL PROBLEMS

An organic orchard is a complex agroecosystem, with many interlinked factors influencing yield, such as:

- Weed control (including management of the alleyway and the understorey in the tree strip)
- Provision of adequate and balanced nutrition
- Pest and disease management
- Variety

Altering one of the components can have undesirable or desirable effects elsewhere. The orchard has to be designed with this in mind and requires a systems approach.

4.6.1. Nutrition and competition

Technical problems associated with nutrition and competition that were reported by growers are as follows:

- Low total yields (few fruit set and few fruit reaching harvest)
- Small fruit size (can be an advantage for some organic markets and storage)
- Unpredictable fruit set and yields
- Poor texture and shelf-life after storage
- Potassium/calcium imbalance (e.g. bitter pit)

Without the use of herbicides to control weeds in organic orchards the alleyway between the tree rows needs to be sown with herbage (usually a grass/clover ley) to suppress weeds. Unfortunately, the herbage itself can cause competition for water and nutrients leading to lower yields and fruit size. However, the alleyway and also the tree strip are multifunctional areas in organic orchards. They provide access to the orchard, habitats for beneficials and can be used to manipulate the balance of nutrient supply to the tree, e.g. mowings can be deflected into the tree strip to increase potassium supply or simply returned to the alleyway (if levels of potassium in the tree or fruit are too high). The ideal situation would be to have minimum intervention to control pests and diseases, this would reduce input costs and labour and could lead to a profitable crop, all be it with lower yields than conventional crops.

The primary sources of nutrients in organic apple and pear orchards are composted materials (e.g. farm yard manure) and the grass/clover ley grown in the alleyways. The main problem with using these materials is not necessarily that they do not provide enough nutrients, it is more that it is relatively difficult to manipulate the release of nutrients and to optimise their use. For example, to get a good fruit set and yield in apples the trees need relatively high levels of nitrogen in the early spring. Unfortunately, soil temperatures are usually relatively low at this time, microbial activity is low and as a consequence the release of available nitrogen is low. In the summer soil temperatures and microbial activity are much higher consequently nitrogen supply can then be too high to get good quality apples.

The supply of potassium can also be too high. Composted materials and the grass/clover ley can provide high levels of potassium. Consequently, it is often the case that organic apples and pears are supplied with excessive levels of potassium leading to an imbalance in calcium in the fruit which can cause bitter pit.

The quality of fresh organic apples is comparable to conventional but after a period of storage they tend to have a poorer shelf life and softer texture than conventional apples. The reasons for this are not clear.

4.6.2. Pest and disease problems

The main disease problems reported for apples are:

- Scab (*Venturia inaequalis*)
- Powdery mildew (*Podosphaera leucotricha)*
- Canker (*Nectria galligena)*

The main pest problems reported for apple are numerous but include:

- Sawfly (*Hoplocampa testudinae)*
- Rosy apple aphid (*Dysaphis plantaga)*
- Other aphids *(e.g. Dysaphis anthrisci, D. devatica, D. brancoi, D. charophylli & D. radicola)*
- Codling moth *(Cydia pomella)* (Could be solved using granulosis virus and mating disruption)
- Apple blossom weevil *(Anthonomas pomorum)*
- Woolly aphid *(Eriosoma langigerum)*
- Leaf curl midge
- Red spider mite *(Panonychus ulmi)*
- Suckers *(Psyllia mali)*
- Winter moth *(Operophtera brumata)*
- Tortrix moth *(Adoxophyes orana)*

4.6.3. Pest and disease problems in pear

These are generally considered as being very similar to apple problems. The main ones mentioned by growers are:

- Scab
- aphids and psyllids

4.7. RESEARCH ABROAD

Far more information was found on organic apple production than pear or soft fruit production but nothing was found specifically on organic cider orchards; these do not appear to have developed abroad.

The Louis Bolk Instituut (LBI) in the Netherlands, the Forschungsinstitut für biologischen Landbau (FiBL) in Switzerland and Winchmore Research Orchard in New Zealand have highly relevant organic top fruit research programmes. Between these three institutes many of the problems highlighted by the UK growers are being researched and some very useful advisory material has been produced in Switzerland.

Some novel approaches to managing herbage in the orchard alleyways and using cover crops in the tree strips are under investigation. There is also some very interesting work on the use of weed-strips to encourage beneficials. Scab spray programmes are being developed which make more effective use of sulphur and rely less on copper compounds (although a replacement for copper which is as effective is yet to be found). The use of pheromones for pest control either for mating disruption or to improve trapping efficiency is also an important area of development.

4.8. GROWER PRACTICE ABROAD

Organic orchards abroad have developed into more intensive systems (2,500 – 3,000 trees per ha) than in the UK. However, tree populations in the organic orchards are still not as high as their conventional equivalents abroad. Irrigation is usually used in these intensive organic orchards to help overcome competition from the grass/clover or mixed herbage leys grown in the alleyways. Intensification may not be the answer in every situation. Some of the profitable and long standing orchards in the UK are much less intensive, the growers circumstances can be such that a system requiring relatively little capital investment but also lower yields per ha is the most appropriate.

The orchards abroad have been designed with organic production in mind. Scab resistant varieties are often chosen for part of the orchard. Single rows of trees are pruned to a height to allow easy management and monitoring of pests. They are trained to allow air circulation to discourage scab and permit effective penetration of sulphur sprays and contact insecticides. Weed strips surround orchard blocks to encourage beneficials. The swards in the alleyways and herbage in the tree strips are also managed with beneficals in mind but are also mown to provide nutrients. Weed control within the tree strips is sometimes achieved by growing the trees through black plastic or woven black plastic but increasingly systems of mowing or shallow cultivations are used.

4.9. PESTICIDES PERMITTED ABROAD BUT NOT IN THE UK

There are a number of crop protection products available to growers in some other EU countries and Switzerland that are not available to growers in the UK. Most are permitted by the organic standards (UKROFS) but they are not permitted by PSD. The most significant of which are:

- **Granulosis virus** against codling moth and summer fruit tortrix moth.
- **Quassia extract** this is effective against both apple and pear sawfly and is expected to be permitted in the Netherlands soon.
- **Pheromones to trap or cause mating disruption.** Pheromones for mating disruption are available in the EU to control codling moth but it is not considered as effective as granulosis virus. *(N.B. use of mating disruption is unclear in UKROFS).*
- **Pyrethrum products and mixtures of pyrethrum and rotenone** are available in Switzerland. These are used to control aphids especially rosy apple aphid, green apple aphid *(Aphis pomi),* woolly aphid

and apple blossom weevil. However, pyrethrum derivatives are broad-spectrum and it would be better to find alternative methods of control.

- **The range of copper compounds** to control scab and canker is limited in the UK.
- **MycoSan, MycoSin & Ullmasud** i.e. acidic clay minerals with various plant extracts are reasonably promising replacements for early season copper sprays for scab control. These are currently permitted in Germany and Switzerland (*N.B. not on UKROFS permitted list).*
- **Neem extracts (Azadirachtin).** These are permitted in Switzerland on nursery trees to control rosy apple aphid. For this purpose it is more effective than pyrethrum, rotenone or soft soap (Häseli et al.,1996). However, neem extracts may pose difficulties registering with PSD. Neem is also relatively broad spectrum as it will kill all phloem sucking aphids its use is probably best restricted to nursery trees. It would be better to find more specific alternatives for wider use in orchards.

5. MAIN CONCLUSIONS AND FINDINGS - STRAWBERRIES

5.1. NATURE OF THE INDUSTRY

There are a large number of growers who produce small quantities of strawberries but a few are on reasonable acreage. According to the organic standards outdoor strawberries have to be grown in a rotation. Although strawberry production is regarded as a specialist activity they are never the only enterprise on a particular farm. Arable and livestock systems are considered the best complimentary enterprises but in practice organic strawberries are often grown within a vegetable rotation.

5.2. FINANCIAL VIABILITY

Initial indications from the MAFF project (OF0151) on the 'Economics of organic fruit production' indicate that organic strawberry production can be profitable. Comparing yields in strawberry systems can be difficult as average figures do not always take into account the maiden year of production, the time in the season or whether the strawberries are raised indoors or outdoors. Although yields can be lower in organic systems there is a premium for grade I organic strawberries and often smaller strawberries are accepted as grade I than on the conventional market. There is also a healthy market for grade II fruit mainly for processing.

5.3. TECHNICAL PROBLEMS

- **Weed control** is the most important problem for growers. In the UK growing the plants in beds through black plastic mulches or woven black plastic has largely solved this. Straw is laid between the beds to control weeds in the pathways. When problems do arise it is usually because perennial weeds were not controlled sufficiently before the strawberries were put in. Some growers prefer not to use black plastic and use shallow mechanical and hand weeding but this is only suitable on light soils where frequent mechanical weeding is possible.
- **Nutrition.** This does not appear to be a major problem although care has to be taken that nitrogen is not oversupplied. This is not normally the case unless poultry manure has been applied. Improvements could be made in optimising the balance of nutrients supplied and the time they become available.
- **Varieties.** There is lack of information on which varieties are most suitable.
- ***Botrytis cinerea.*** As in conventional systems it is the most important disease problem. Growers rely on cultural methods of control, there are no organic sprays that are effective and there is no significant varietal resistance.
- **Powdery mildew** can also be important but mainly in protected cropping. Varieties with some resistance are available.
- ***Verticillium*** and ***Phytophthora*** rots are avoided by using rotations, by soil testing and using healthy runners but they can be devastating if things go wrong. There is then nothing a grower can do except give up growing strawberries. One of the *Phytophthora* rots *P. fragariae* is a notifiable disease anyway.
- **Pests.** No particular insect pest seems to be a significant problem but many species occur at low levels. The complete absence of sprays may encourage beneficials and existing organic growers tend to have small fields with diverse hedgerows.
- **Slugs.** These can be a problem in wetter areas and on some soil types.

5.4. PRACTICE AND RESEARCH ABROAD

In most countries growers seem to use a similar method as in the UK with the exception of the Danish who tend to use mechanical weeding rather than mulching. A significant problem with strawberry blossom weevil has developed in Sweden, which tends to occur in areas where there are forests.

Research programmes abroad tend to be focusing on cultural methods of disease control and there are some promising biological control agents emerging from conventional research programmes. Encouragement of beneficials using weed strips is also gaining some attention but nutritional aspects are largely neglected apart from some work monitoring mycorhizal associations in the USA.

Advisory material is available from FiBL in Switzerland and recently rough drafts of Swedish material used in grower courses have been obtained.

6. MAIN CONCLUSIONS AND FINDINGS – CANE AND BUSH FRUIT

6.1. NATURE OF THE INDUSTRY

The majority of growers in the UK are on small acreages and market through box schemes, 'PYO' or farm shops. There is also a market for processing and juicing for some of the crops. So far it has not been possible to draw conclusions about financial viability as there are too few growers with significant acreage from which to draw data.

6.2. GROWER PRACTICE

Weed control is an important problem. For some crops mulching is suitable but on the whole there is a lack of information about how to use them. In raspberry growing most growers weed the crop rows by hand and have a grass/clover ley in the pathways. Various training systems for canes are used to support the plants and get good air circulation to avoid disease.

6.3. MAIN TECHNICAL PROBLEMS

- Weed control.
- Management of the pathways to manipulate nutrient supply.
- Providing balanced nutrition.
- Raspberry beetle.
- Lack of information on suitable varieties.

It is difficult to predict whether other pests and diseases will become a problem if the size of plantations increases. Potential problems are gooseberry sawfly, gall mite in blackcurrants, vine weevil in cane fruit, and cane blight/midge complex.

6.4. PRACTICE AND RESEARCH ABROAD

One soft fruit grower was visited in the Netherlands who grew mainly raspberries, redcurrants and blackcurrants. Their practice was much the same as in Britain but some of the crop was grown under polythene tunnels to prevent rain damage and to spread the season.

Very little information could be found specifically on organic soft fruit. The only significant study found was done in Sweden on the effects of different mulches and management of the sward in the pathways of blackcurrants. There may be some literature from Germany on organic soft fruit but attempts to contact researchers did not yield responses and database searches did not identify any papers.

Some work carried out for conventional production is of relevance, this is mainly related to breeding for resistance to pests and diseases, the use of biological control agents and pheromone trapping and mating disruption.

A booklet on organic cane and bush fruit production is available from FiBL but it has not been translated. There is also some information available in draft form from advisors in Sweden on raspberry production. Limited information is available on the Internet mainly from websites in the USA but this tends to be information on conventional production adapted for organic production.

7. SUGGESTED APPROACH TO RESEARCH IN THE UK

A suggested approach is to use grower participatory trials to complement detailed experiments in organic research orchards and plantations. There has been a great deal of interest and offers by growers in the UK to do trials on their farms. Grower participatory trials have their risks, i.e. problems in communication, trials can be 'lost', and researchers often have to travel long distances, which can reduce time efficiency and incur travel costs. The co-ordination or general direction of the trials can also become fragmented.

However, various degrees of grower participatory trials have proved successful elsewhere. Trials are carried out under what is considered best organic practice for a particular grower's situation. By doing the trials in real orchards and fields this seems to help ensure that a systems approach is achieved and that ideas work in the practical situation. Often the trials provide a focus for 'Open Days' and discussions between growers and researchers. This keeps the research focused on the growers needs and enables growers to see ideas in operation on a semi-farm scale. Some of the suggested research priorities in the following sections are highly suitable for grower participatory trials. Others are not; where frequent measurements or assessments are needed an 'on station' trial or a site close to the researcher is likely to be more practical and efficient.

It was quite noticeable during the study that the most relevant and rapid research comes from programmes where one organisation plays a central role in a particular country. This organisation is either from the traditional organic movement or has a high level of commitment to the movement. There is a strong collaborative approach with advisors, growers, other research organisations and Universities. This could be an illusion because it is a lot easier to collect information from a centralised point but it could be that researchers and advisors communicate and make more progress if they are collaborating with a central 'unit'.

Agricultural and horticultural colleges are probably an under utilized resource. Perhaps some practical trials could be carried out in college orchards. This would provide students with the opportunity to experiment within an organic system and it is an important route for technology transfer.

Small independent organisations such as the Agroforestry Research Trust and nurseries propagating trees, runner plants, canes etc for the amateur organic market could provide practical experience and trial areas for research on propagation.

It is important that researchers who become involved with organic fruit production pursue links developed during the project with Europe. Exchange visits would be very worthwhile to enable sharing of ideas and experience. This will also prevent unnecessary duplication of work and help to provide a co-ordinated approach where multiple sites strengthen research programmes. All of the researchers and advisors in Europe seemed to be keen to collaborate although initially it may be easier for individuals from organic organisations to gain co-operation. Organic departments and organisations get many requests for collaboration and it can be hard to decipher which are genuine.

Language can become a frustrating and significant barrier especially for technology transfer. Several of the researchers and advisors from abroad (e.g. Holland and Sweden) wish to translate information into English or visa versa but can not achieve this from their own resources or access other funds to do this. Technical translators are extremely expensive and do not necessarily produce wholly accurate material.

8. SUGGESTED RESEARCH PRIORITIES FOR UK TOP FRUIT

There is considerable urgency to get four products or product types accepted by the UK Pesticide Safety Directorate i.e. (1) granulosis virus, (2) pheromone mating disruption methods, (3) pheromone traps for pest control rather than monitoring, (4) Quassia. The acceptance of these products could save considerable research effort and money searching for other solutions.

The following list of priorities does not include research topics which it is felt would be solved by using the above four product types. It does include priorities identified in the conclusions of past research projects mainly from the Netherlands, Switzerland and New Zealand that are applicable to the UK. Where work on a particular priority is already being carried out elsewhere this is indicated in brackets.

The most urgent research priorities are:

- **variety trials** and selection of suitable breeding material
- **scab control** cultural controls and optimising 'chemical control'
- **weed control/water/nutrients** including intensive irrigated systems, methods to reduce reliance on irrigation (e.g. rootstocks), management of the orchard alleyway, management of the tree strip, optimising the supply of nutrients from composted materials and finding suitable foliar and liquid feeds
- **pest control** use of weed strips and addressing specific pest problems (rosy apple aphid & aphids in general, apple blossom weevil) including searching for biological control methods and pheromone trapping or mating disruption.

8.1. VARIETY TRIALS

Although it was hoped that during the course of this review suitable varieties for organic production would be identified, this did not prove possible. Ideally multiple organically managed sites are required, these could be co-ordinated with grower participatory trials and existing informal trials which growers are already carrying out in their own orchards. It would be useful to include some of the varieties recommended on the continent. Varieties that have resistance genes other than 'Vf' could also be included.
('Vf' is the most commonly used major gene for resistance against scab and there is evidence that this resistance may break down because resitance breaking isolates of *V. inaequalis* already occur in the population).

Primary objectives need to be scab and pest resistance and to a lesser extent mildew resistance. Yield and quality should be assessed and there is a particular need for varieties that store well (either in air storage or controlled atmosphere storage) and have reasonable shelf life. It is also important to do some ‘consumer acceptance trials’ on the most promising varieties.

8.2. SCAB CONTROL

It is unlikely that varieties which are resistant to scab will be available that satisfy all the requirements of the different markets. Scab susceptible varieties will continue to be grown in the near future, some varieties may only be partially resistant and there is always the danger that 'Vf' resistance will break-down. It is therefore important that other control methods are developed along side the use of resistance. Possible avenues of research are:

a) To test the efficacy of cultural methods to promote rapid leaf breakdown and reduce overwintering of scab, especially in cool dry winters when leaves do not break down naturally, e.g. mowing or macerating leaf debris, the addition of substances to assist break down, conditions to promote endemic biological control agents and introduction of biological control agents or antagonists.

a) To test the recommended spray programme used in Switzerland, e.g. there is a need to trial ‘Bordeaux mixture’ at the copper rates suggested. The spray programme is based on copper compounds such as copper sulphate, tetracopper oxychloride and cuprous oxide that are used abroad. This will only be appropriate if copper is still going to be permitted after 31st March 2002.

c) To test the efficacy of the different sulphur and copper products available in the UK. British growers have noticed that different products with apparently the same formulation wash off more easily than

others, this will influence spray intervals. Likewise spray equipment varies enormously in efficiency. Also to obtain some of the sulphur products available in Europe especially more of the wettable products which are recommended in Swiss spray programmes.

d) To obtain scab forecasting systems used in Holland and compare their efficacy with forecasting systems and spray products available in the UK. *(A project has just started in Holland looking at the forecasting systems available there but conditions and the products available to growers are probably sufficiently different to warrant separate UK trials).*

e) To find replacements for early season use of copper in scab spray programmes. *(Similar work is being carried out in Holland, Switzerland and New Zealand but no real solutions have been found yet.)*

f) To test the use of seaweed extract, costs v benefits. A number of growers regularly spray with seaweed extract as a 'tonic' at the same time as applying sulphur. Observed effects are greener leaves and a synergistic effect with sulphur for scab control but the mechanisms are poorly understood. Sea weed extract is known to contain only small amounts of major plant nutrients so it can not be classed as a foliar feed although it does contain significant quantities of minor plant nutrients. The effect of the product on growth, yield and scab control needs further investigation especially an evaluation of the costs of the product versus its benefits. *(A number of research projects have been published on the effects of seaweed extract on other crops. A summary of fruit trial work commissioned by 'Maxicrop International Ltd' should be available soon; it is probably best to wait until this is available.)*

8.3. WEED CONTROL/WATER/NUTRIENTS

8.3.1. Intensive irrigated systems

Most of the high yielding organic orchard systems used abroad use single row but high intensity plantings (2,500 – 3,000 trees per ha). The trees are often trained along wires. Irrigation is used; usually some form of trickle irrigation that is run along the bottom wire used for training the trees. It would be useful to compare the yields of this sort of system with a slightly less intensive system without irrigation (which is commonly used in conventional systems in the UK) to see if the extra capital investment is worthwhile. Irrigation may be the only way of overcoming competition from the understorey/ alleyway sward.

8.3.2. Rootstocks - reducing the reliance on irrigated systems

Most of the intensive systems abroad use M9 rootstocks as it is important to control the vigour and size of the tree for easy monitoring and management. M9 rootstocks are not particularly good at taking up water and nutrients. Trials on new rootstocks or combinations of 'interstem grafting' and rootstocks needs to be carried out. These should ultimately be tested in an organic system e.g. where shallow cultivations are used for weed control. *(To my knowledge trials specifically testing different rootstocks in organic systems are not being carried out elsewhere).*

8.3.3. Management of the alleyway

Grass/white clover leys are the most commonly used between the rows of trees. Trials on alternative species which are less competitive for water and nutrients and how best to manage these in terms of (i) mowing strategies to manipulate nutrient availability (especially potassium) and minimise competition for water, (ii) to provide habitats for beneficial and predatory insects, (iii) regulate the growth of the trees, (iv) still provide access for machinery. *(Research programmes along these lines are being carried out in Holland, Switzerland and New Zealand but it is a very important subject area for improving yield and quality).*

8.3.4. Management of the tree strip (i.e. the area directly surrounding the trunk)

a) Trial of different winter cover crops in the tree strip

In systems where the tree strip is cultivated for weed control during the growing season there is the opportunity to plant winter cover crops. These can then be either left to frost off or be cultivated in during the early spring. This may be a way of manipulating the availability of nitrogen in the early spring when it is required to get good fruit set. Possibly this approach could be combined with the use of the 'sandwich system' under trial in Switzerland which includes the use of non-competitive herbaceous species attractive to beneficial insects in the tree strip. *(Trials have started in Netherlands relatively recently but not combining green manures with the sandwich system).*

b) Trial of equipment available to weed the tree strip
There are various mowers, cultivators, flame weeders and infrared weeders available in the U.K. and Europe. It would be useful to trial these alongside one another and to compare their performance in terms of weed control and effects on yield, quality, nutrient availability (flame weeding is likely to release potassium) and damage to the tree.

8.3.5. Supplementing primary nutrient sources with liquid and foliar feeds
There are relatively few sources of nutrients available to organic growers. The primary nutrient supply has to be from composted materials and mowings from the orchard alleyways, further investigation is required to optimise the balance and timing of nutrient releases from these sources.

Short term solutions may be required in some circumstances and on different soils. Liquid feeds or foliar feeds will be needed to rectify nutrient deficiency or imbalance. Organically acceptable feeds need to be developed (especially replacements for slaughterhouse products). The undesirable effects of increasing nutrient supply (e.g. increases in nitrogen can increase pest or disease levels) need to be taken into account when testing the efficacy of products. *(There is a trial in the Netherlands but only using a very small range of products and side effects on pests have been observed but are not particularly monitored.)*

8.4. PEST CONTROL
Optimising methods of pest prevention, e.g. weed strips, and control methods for specific pests need investigation.

8.4.1. The role of floral strips in pest control
Investigations on how design, shape, width, management etc of floral strips influence beneficials and their effects on insect pest control. Recent work in Switzerland has indicated that spiders may be far more important at controlling aphid populations than previously thought. However, not all trials have been successful. It appears that the location of the floral strip, probably its management (e.g. if and when it is cut) and competition and health of the tree are confounding factors. *(Experiments are being carried out in Switzerland but it is a vast subject area and there is scope for more research as it the first line of defence in organic systems for insect pest control especially aphids. The plant species in the strips and the role of different parasitoids, predators, alternative food sources for predators etc. need to be tailored to the UK. Pest and disease control products used in the UK may also influence predators and this may be an important difference to investigate.)*

8.4.2. Use of low growing non-competitive plant species within the tree strip
Screening of different indigenous U.K species that are non-competitive and attractive to beneficials, parasitoids, spiders and beetles for pest control. *(Trials are being carried out in Switzerland along similar lines.)*

8.4.3. Pest control programme recommended by FiBL
It would be useful to trial the programme recommended by FiBL using the limited range of products available in the UK. Some of the pest thresholds and optimum timings for monitoring or spraying may be different in the UK.

8.4.4. Replacements for Derris/Rotenone
a) Rosy apple aphid control & aphids in general. Spot treating with soft soap is reasonably successful for early season control before the leaves curl. Later the only option is to use Derris but this tends to do more harm than good as it kills predators. A novel alternative such as a biological control agent is required. *(Trials with Neem have proved effective in Switzerland but it is unlikely to be registered here).*

b) Sawfly. Has been highlighted as a very common problem Quassia has been found to be fairly effective elsewhere (it is not permitted in the UK yet) but the timing of application is very critical. Derris can be used but is broad spectrum and not very effective. The use of Quassia in an integrated system needs to be tested and/or other methods such as use of traps, pheromones and parasitoids investigated. *(Some work in IPM*

systems are being carried out on traps, pheromones and parasitoids but these are being developed for more effective use of pesticides rather than for avoiding the use of pesticides altogether.)

8.4.5. Decision support for the use of rotenone/derris

If rotenone is to remain an important organic pesticide it would be useful for growers to know pest thresholds at which spaying is worthwhile i.e. is the degree of control obtained for a particular pest worthwhile in relation to the increased risk of another pest becoming a problem because beneficial insects are killed.

8.4.6. Woolly apple aphid

Although early season spot treatments with soft soap and physical removal of colonies can be effective, measures to control it later with soft soap are not. More effective non-broad spectrum methods would be useful (*Neem is not effective, apart from the use of eawig shelters other methods such as the use of parasitoids do not appear to be well investigated. Trials on woolly aphid resistant rootstocks are being carried out in New Zealand.)*

9. SUGGESTED RESEARCH PRIORITIES FOR STRAWBERRY PRODUCTION

9.1. VARIETY TRIALS

Organic growers are often able to make sensible judgements about varieties based on information obtained from conventional trials. However, as with other crops, pest and disease resistance are not the highest priority in conventional trials and it is likely that some breeding lines could have been discarded from conventional trials which would be better suited to an organic system. There is considerable pressure from the retail market to use varieties such as 'Elsanta' but it is not considered an easy variety for organic production. *(Variety trials are carried out elsewhere in Europe but these are not particularly relevant to the UK because of different climatic conditions and consumer preferences.)*

9.2. ONE YEAR CROPPING SYSTEMS VERSUS TWO OR THREE YEAR SYSTEMS

One year production systems are supposed to have fewer problems with pests and diseases and recommended in Switzerland for outdoor crops. It would be useful to compare pest and disease levels to see if the extra replanting costs are worthwhile. Nutrient budgets also need to be considered within this approach.

9.3. MANAGEMENT OF POLYTUNNEL AND PROTECTED CROPPING SYSTEMS (PLANTS MUST BE GROWN IN THE SOIL)

In Switzerland the use of polythene tunnels have not proved as successful as hoped. If carefully managed they can reduce *Botrytis* but this is not always the case and powdery mildew can become a problem.

9.4. *BOTRYTIS* CONTROL

- Efficacy of cultural methods such as removal of debris, plant spacing and effects of nutrient supply. *(Work is being carried out in Denmark on all three factors but they use mechanical cultivation for weed control rather than plastic mulches as in the UK).*
- UV light filters for polytunnel cladding *(There is some industry funded research work in the UK in conventional systems but it is important that any negative effects such as increases in powdery mildew or reductions in predatory insects are fully investigated).*
- Use of biological control agents used abroad in combination with cultural control methods. *(Biological control agents are already available in Denmark but give variable results)*
- Screen alternative 'natural' chemicals for control of *Botrytis.*
- Investigation of white light to delay *Botrytis* postharvest. *(An initial study has been carried out in conventional strawberries but Botrytis control was not the primary aim of the trial)*
- Variety trials. Some varieties are less prone to *Botrytis* than others probably because of characteristics such as plant habit.

9.5. POWDERY MILDEW CONTROL

This can occasionally become a problem outside but is more of a problem in polythene tunnel systems. Possible avenues of investigation are:

- The use of resistant varieties and cultural control methods such as removal of plant debris *(Some work is underway in Denmark)*
- Further investigation of the importance of cleistothecia in initiating epidemics and a better understanding of what triggers their formation. *(Some work has been carried out in conventional systems at HRI East Malling)*
- Use of biological control agents and alternative natural compounds. *(Sodium bicarbonate is under trial in Sweden)*

9.6. *VERTICILLIUM* AND *PHYTOPHTHORA*

Optimising the use of rotation to prevent soil borne diseases. For example,

- Optimum crops for rotation and making use of biocidal crop residues (e.g. brassica residues) *(Some work is being carried out on this in a conventional system at HRI East Malling.)*
- Crops or cultural methods which encourage antagonists.
- Manipulating conditions for promoting the decline of soil borne pathogens.

9.7. NUTRIENT SUPPLY

It would be useful to investigate ways of providing a balanced nutrient supply low in nitrogen in relation to potassium and phosphorous, for example:

- Use of cover crops in the paths between beds to manipulate nutrient balance. Shifting the balance of nitrogen supply to the spring and/or when plants are establishing without causing greater susceptibility to pests and diseases.
- Use of different coloured mulches to manipulate soil temperatures, microbial activity, mycorrhizal associations and subsequent nutrient release.
- Use of organically acceptable liquid and foliar feeds to rectify nutrient imbalance.

9.8. PEST CONTROL- ENCOURAGEMENT OF BENEFICIALS

A better understanding is required of the role of weed strips to encourage beneficials including carabid beetles. Possible avenues of investigation are:

- Which plant species are best to use
- how to position the weed strip
- when they should be cut.

(Some work has already been done in low pesticide input systems but even occasional sprays can result in a different distribution of beneficials from those encountered in an organic system where sulphur is the only spray used.)

- Effects of one, two or three year cropping systems on the build-up of beneficials.
- Effects of mulches on vine weevil and carabid beetle populations.

9.9. SLUGS

Use of biological control agents in combination with cultural control methods. *(Biological control agents are available in Switzerland there has been some work on manipulating conditions to favour the biocontrol agent in HDC trials in vegetable production but not strawberries where mulching systems are used).*

10. SUGGESTED RESEARCH PRIORTITIES FOR CANE AND BUSH FRUIT

Raspberry and blackcurrants are probably the most important crops to pursue.

10.1. VARIETY TRIALS AND BREEDING PROGRAMMES

These are required especially for disease resistance but also for their competitive ability for nutrients and water. (*Some blackcurrant varieties have been shown to be more sensitive than others to competition from*

swards in the alleyways and weeds in the crop strip so varietal suitability for organic systems may be worth pursuing.)

10.2. WEED CONTROL/WATER/NUTRIENTS

10.2.1. Management of alleyways

- Evaluate suitable species to avoid competition for nutrients.
- Mowing regimes to manipulate nutrient release.
- Possible use of short term cover crops to minimise competition and manipulate nutrient release.
- Use of alleyway and its management to maximise beneficials.
- Investigate whether the herbaceous alleyway alters the incidence of diseases, pests or beneficial insects.

10.2.2. Management of the crop rows

- Look at optimum width of mulched or weedfree strip to minimise competition. Compare costs of two approaches and benefits in terms of yield.
- Investigate effects of mulches vs hand weeding or cultivation on pest and predator populations.

10.3. PEST CONTROL

10.3.1. Use of weed strips to encourage beneficial insects

As for strawberries beneficial insects are probably playing a role in pest and disease control in bush and cane fruit but position of the strips, plant species composition and cutting regime need optimising.

10.3.2. Raspberry beetle

- Effect of organic practices e.g. mulching and use of herbage in the alleyway on pest levels.
- Use of pheromone traps. (*Some work is already in progress at SCRI for IPM systems)*
- Use of bucket traps (buckets of water containing some fruit – beetle is attracted and drowns in bucket). *These are under trial in America for a closely related beetle species.*
- Evaluation of the practicality of poultry to reduce raspberry beetle infestation.

10.3.3. Raspberry cane midge and blight complex

- Investigate methods to remove the first flush of canes e.g. strimming or flail mowing. Look at effects on other pests and diseases.
- Investigate practicalities of only allowing canes to fruit biannually. Look at effect on other pests and diseases to see if their life cycles are also interrupted sufficiently for cost effective control.

10.3.4. Gooseberry sawfly

- Investigate whether mulching and the herbage in the alleyway influences incidence of sawfly.
- Investigate alternatives to rotenone. Traps, natural pesticides, Quassia, biocontol agents

11. DISSEMINATION OF INFORMATION

11.1. APPROACHES TO FUTURE DISSEMINATION OF WRITTEN INFORMATION

Approaches to the dissemination of results was discussed at the Organic Fruit Focus Group Steering Committee Meeting held on the 12th of October 1998. At that time there were two main avenues for distributing written information in the form of booklets or leaflets was concerned.

- The feasibility of HDRA collaborating with FiBL to produce translations of Swiss booklets in English.
- The production of booklets or leaflets which drew on information from several sources. It is likely that these will be produced in collaboration with the Soil Association.

11.1.1. Translation of FiBL booklets

Collaboration with FiBL and translation of their booklets on fruit could provide a relatively quick way of providing British growers with information. Production costs of the colour illustrated booklets could be cut by sharing them with the Swiss. Concerns were expressed during the meeting that the FiBL booklets would

need adaptation for the UK situation. For example, many of the permitted chemicals used by the Swiss were not available or permitted in the UK, also major pest and disease problems may be different.

The director of FiBL, Urs Niggli is keen to collaborate and the matter has been discussed with Alan Gear of HDRA. The Swiss expressed the same concerns and it was agreed that if translations were produced and published that they would need to be adapted for the UK. Formal contracts between FiBL, HDRA and a funding body would have to be set up to enable joint publication.

In order to obtain information for the current review three FiBL booklets have been translated into English and are in a rough draft form:

- **Pest and disease control in organic apple production.** Translated by Liza-Maria Broomfield, HDRA.
- **Organic strawberry production.** Translated by Till Pellny, HRI East Malling.
- **Varieties for organic top fruit production.** Translated by Till Pellny, HRI East Malling.

The first two booklets are the most relevant. The third, 'Varieties for organic top fruit production' is not so relevant to the UK grower as many of the varieties seem to be more appropriate for continental consumer preferences.

The translated drafts of the booklets have provided invaluable reference sources in the review but they still require considerable editing, adaptation and peer review before they would be suitable for publication. This would require further time and funding.

Other useful booklets by FiBL that are worth translating are:

- **Management of orchards to encourage beneficial insects and wildlife**
- **Organic soft fruit production**
- **Pest and disease control in organic cherry production**

11.1.2. Booklets and leaflets drawn from several sources of information

It is intended that at least one booklet will be released through the Soil Association Technical Guides for Organic Food Production. Drafts of two booklets 'Organic Apples – Pest and Diseases Management' and 'Organic Strawberry production – A growers guide' have been produced as part of the current review (See Appendices 2 and 3). These still need peer review. Draft advisory information received from Sweden during the closing stages of this project still needs to be evaluated and incorporated into the booklet on strawberries.

To a certain extent there is a dilemma that the Soil Association Technical Guides may supersede the Swiss translations. However, in some respects the Swiss booklets contain much more information and illustrations e.g. on the identification of pests and diseases. One solution may be to work on the three booklets that still have not been translated.

11.1.3. Circulation of information through the Organic Fruit Focus Group

The time scale to produce either the FiBL translations or the Soil Association Technical Guides is a major concern to growers who desperately need information quickly. One approach would be to circulate drafts of the booklets intended for the Soil Association Technical Guides through the Organic Fruit Focus Group. This would not happen before initial peer review has been completed but it would provide the opportunity for a wider peer review. The disadvantage with this is that the booklets would be open to copyright abuse.

A second approach would be to produce short leaflets on more specific topics that have been requested by growers,e.g.

- The report of the Dutch study tour (see appendix 4).
- Where to buy resistant varieties
- Crop protection chemicals and biological control agents permitted in the UK
- The use of sea weed extract

- Establishing an organic orchard

This may help satisfy the immediate need for information but even this approach would require some funding. At present the Organic Fruit Focus Group does not possess its own funds. Administration costs are currently borne by HDRA and there is some support by the Soil Association who help organise joint seminar/farm walk events.

11.2. DISSEMINATION THROUGH WORKSHOPS CONFERENCES ETC.

At the request of The Organic Fruit Focus Group steering committee a presentation on apple production was given in January 1999 at the 11th National Conference on Organic Food and Farming.

It was also decided at the project steering committee meeting that ideally two more events should be held during the year.

- A 'Conference on Prospects for Organic Fruit Production' will be held at HRI East Malling on the 11th May 1999. This is a collaborative event organised by the East Malling Research Association, the Henry Doubleday Research Association and the Soil Association. The day will cover both top fruit and soft fruit and will include a talk on the review project. The event is targeted at conventional growers and those considering conversion.
- A second event targeted at existing organic growers who require more technical information to be planned for later in the year. This will include a farm walk and will be a collaborative event between HDRA and the Soil Association.

11.3. DISSEMINATION TO DATE

Seminar and farm walk. *'Organic Top Fruit Production'*. Held on the 3rd March 1998 at Marden, Kent. This was an event mainly for growers, which was organised by the Soil Association, the Organic Fruit Focus Group and the Henry Doubleday Research Association.

Grower/Industry study tour to the Netherlands, 19th-20th August 1998.

A two day visit to the Netherlands was organised by HDRA and the Louis Bolk Instituut. Members of the Organic Fruit Focus Group and other interested parties were invited. Nine people attended three were organic growers, two were researchers, two were involved in marketing, one was an advisor and one was a head gardener of a private estate. Two farms were visited, a report of the visit was produced, and this was circulated at the 11th National Organic Conference on Organic Food and Farming (See appendix 4 for the report).

Conference presentation/paper. Bevan, J. (1999) *'Organic Apple Production – experiences from Switzerland, Holland and the UK'*. Abstracts and Biographies. 11th National Conference on Organic Food and Farming. 8th-10th January 1999.

Presentation. *'Review of organic fruit production and research needs'*. Organic fruit seminar for researchers at HRI East Malling. 27 April 1998.

Popular press article. Bevan, J. (1998) *'Organic Fruit Focus'*. In: Growing Organically, 152, 30-31. The Henry Doubleday Research Association Magazine. Ryton Organic Gardens, Coventry, CV8 3LG.

Steering committee minutes (12th October 1998). A summary of the progress of the project and discussions on the dissemination of the results was circulated to the Organic Fruit Focus Group in November 1998.

11.4. DISSEMINATION IN THE NEAR FUTURE

Study tour report. *'Visit to Holland –2 Organic Fruit Farms (19th-20th August, 1998).* This will be circulated through the Organic Fruit Focus Group in June 1998 (see appendix 4).

Popular press article. Bevan, J. (1999) *'Organic Fruit Focus'*. In: Growing Organically, 155. *In Press.* The Henry Doubleday Research Association Magazine. Ryton Organic Gardens, Coventry, CV8 3LG.