DEFRA HORTICULTURE LINK

Varieties and Integrated Pest and Disease Management for Organic Apple Production

HORTLINK Project HL0150LOF

FINAL REPORT

Consortium members:
Horticultural Development Council (formerly Apple and Pear Research Council)
The East Malling Trust for Horticultural Research
Fourayes farm Ltd
Fruition Ltd
Henry Doubleday Research Association
East Malling Research
North Court Fruit Farm
OrchardWorld Ltd
Sainsbury's Supermarkets Ltd
E H Wilson and Son
Waitrose Ltd

Government sponsor
Defra

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CONSORTIUM MEMBERS

The following are members of the Consortium for LINK project HL0150LOF:

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Varieties and Integrated Pest and Disease Management for Organic Apple Production

GROWER SUMMARY (FINAL REPORT)

Headline

Best practice approaches for Integrated Pest and Disease Management (IPDM) for organic apple production have been developed and shown in large-scale field trials to allow substantially improved results. The crucial importance of disease resistant varieties has been demonstrated. Converting established conventional orchards of disease susceptible varieties (Cox, Gala, Bramley, Fiesta etc) to organic production is not likely to be successful. A better approach is to plant new orchards of scab resistant varieties. Partial control of scab and mildew may be achieved by early season copper sprays and growing season sprays of sulphur respectively. Early season sprays of pyrethrum have been shown to give acceptable control of apple blossom weevil, the most important pest, and late season sprays of pyrethrum to give 80% control of rosy apple aphid.

Five dessert and four culinary disease resistant apple varieties of acceptable quality have been identified by the consortium which includes two important multiple retailers, Waitrose and Sainsbury's. These are to be recommended to organic growers in the near future.

Background and deliverables.

A 5 year research project funded under the DEFRA Horticulture LINK scheme to identify suitable varieties and develop an effective Integrated Pest and Disease Management (IPDM) programme for organic apple production has been completed.

Summary of the project and main conclusions

Objective 1a. Development of an effective Integrated Pest and Disease Management programme

Scab

- The results demonstrate the crucial importance of scab resistant varieties for organic apple production. Spray programmes of copper and sulphur did not prevent damaging scab infection on susceptible varieties in high risk scab years, even though they gave reasonable control in low risk years.
- Converting established conventional orchards of disease susceptible varieties (Cox, Gala, Bramley, Fiesta etc) to organic production is not likely to be successful.

- A better approach is to plant new orchards of disease resistant varieties. Scab resistance is vital and mildew resistance is vital in mildew prone areas. (The variety Pinova is too susceptible to both scab and mildew for organic production).
- Destruction of overwintering sources of scab on leaf litter (e.g. by maceration) is important to reduce inoculum.
- Three early season sprays of copper at the recommended dose (1 pre-bud burst, 2 at bud burst and mouse ear) gave fairly good early season control of scab on fruit and rosette leaves, ensuring a crop, but may not prevent a severe subsequent build up of leaf infection on extension growth during summer.
- Sulphur had at best only limited activity against scab.

Mildew

- Minimising primary mildew incidence by removal during winter pruning and in spring (primary blossom mildew and primary vegetative mildew) will improve growing season control of mildew and is an essential part of the integrated approach.
- Highly mildew susceptible varieties like Pinova should be avoided for organic production in mildew prone areas because they will require intensive sulphur spray programmes to control mildew effectively.
- A programme of sprays of sulphur at 50-100% dose is moderately effective for mildew control but the programme has to be maintained throughout the period of extension growth (April-August). Higher volume sprays at the full dose are necessary in mildew prone areas on susceptible varieties.

Sooty blotch

- Sooty blotch colonisation of fruits is likely to be a serious problem in organic orchards with poor air circulation, which favours the disease.
- Spray programmes of copper and sulphur had at best only limited effects.
- A better understanding of the epidemiology of this fungus is essential if alternative means of controlling this disease in organic production are to be identified.

Leaf spot

- Leaf spots caused by *Phoma* sp. or *Botryosphaeria obtuse,* although normally present at low incidence and causing little damage, under favourable warm wet weather can spread rapidly, causing premature leaf fall and some spotting to fruit.
- Early season copper sprays appeared to give very little control of the problem.
- Additional work may be needed to understand the epidemiology and significance of these diseases.

Apple blossom weevil

- Apple blossom weevil was the most important pest causing large losses in yield and quality in the established orchard where it occurred. It did not occur in the newly planted orchard, which was isolated from sources of infestation during the first three years of establishment.

- Parasitism by the parasitic wasp *Scambus pomorum* varied greatly from year to year and did not naturally regulate apple blossom weevil numbers sufficiently to prevent significant crop damage by the pest.
- Two early season sprays of pyrethrum (Py Insect Killer) targeted against adults around bud-burst were shown to give fairly good (~80%), though not complete, control of apple blossom weevil. A single spray was less effective and sprays of rotenone (Derris) were ineffective.
- Use of sprays of pyrethrum to control apple blossom weevil does not fit well with the aims of organic production and alternative control strategies, based on the use of the weevil's aggregation pheromone, need to be developed.

Rosy apple aphid

- Rosy apple aphid caused significant damage to the young trees in the newly planted orchard.
- It was much less of a problem in the established orchard, even in spring 2004, when the pest was at very high levels in conventional orchards throughout SE England.
- The variety Topaz was considerably more susceptible to infestation than Pinova.
- Early season pyrethrum sprays (for apple blossom weevil) gave some reduction in infestation.

Codling moth

- Although codling moth is a key pest of apples that is known to cause serious economic damage at low population densities, it was not a significant problem in the first 4 years of experiment 1, despite high, above threshold pheromone trap catches.
- However, the need for codling moth treatment in organic systems was demonstrated in 2004 when significant damage (8%) was caused, mainly by the second generation in August-September. Sprays of codling moth granulovirus provide an organically acceptable control method for codling moth.

Early season caterpillar damage

- There was a moderate incidence (<10% fruits at harvest) of early season caterpillar feeding on blossoms and young developing fruits, which resulted in blemishes on fruits at harvest. Early season *Bacillus thuringiensis* sprays did not greatly reduce the incidence of this damage.

Tree nutrition

- N levels in leaves and fruits in the newly planted and established organic orchards were usually below the target levels considered optimal for conventional production and the foliage had a general yellowish, N deficient appearance.
- Application of organic high N fertiliser analysis appeared to improve levels in one experiment, but not to the optimal level.

- Low N levels are likely to have significant adverse affects on tree growth, bud strength and fruit set and are likely to be a cause of erratic and low average yields in organic apple production.
- For successful organic apple production, means of overcoming competition from ground herbage for moisture and nutrients and of provision of N are likely to be of vital importance to successful organic production.

Yield and quality

- The experimental treatment on average produced a 50% greater harvested and marketable yield than the grower's treatment, which in turn yielded 33 % more than the untreated control on average.
- Differences in yield were caused by differences in the numbers of fruits harvested.
- The experimental treatment generally had the highest percentage of fruits in the Class I quality grade (5 year averages class I: 44% experimental, 30% growers, 28% untreated).

Economic results

- Financial returns (net margins) from the experimental treatments were consistently higher than both the grower and untreated ones (see Table S1 below).
- Financial returns from the experimental treatments were less variable than both grower and untreated ones and always positive.
- The costs of the IPDM programme used on the experimental treatments, at 4% (2p/kg) of total costs of growing and marketing, were relatively small and easily justified in terms of the increased financial returns (2.3 fold) relative to the growers.

Table S1.The gross economic output (£/ha) from the IPDM trial in the established organic Fiesta orchard

Year	2000	2001	2002	2003	2004	Average
Untreated	2,725	7,646	115	17,600	10,488	7,764
Growers	10,519	9,647	831	23,727	6,656	10,276
IPDM	12,420	18,270	8,016	26,751	22,553	17,602

Objective 1b: Identification of products to enhance apple leaf rotting in the autumn

Five separate experiments, the latter two at each of two sites, were conducted to test alternatives to urea for post harvest treatment to encourage rotting of apple leaves on the surface of the ground in the orchard post harvest. Fiesta leaves collected from an organic apple orchard before leaf fall were dipped in solutions of the test treatments in December, then held on the surface of the ground in batches of 30 in the test orchard. The numbers of leaves that disappeared subsequently due to degradation and removal

by earthworms was assessed at intervals during the dormant period following treatment. The main conclusions were as follows:

- None of the treatments evaluated at standard rates were as consistent or as effective in encouraging leaf decay as urea.
- Sea Vigour (Fish oil) and Nugro (4000 ppm N = ten times normal rate) encouraged leaf rotting compared to the untreated in some seasons and may be worth including as post harvest pre leaf fall treatments.
- Compost tea (bacterial or fungal) was completely ineffective and may have delayed leaf rotting.

Objective 1c: Testing of products for sooty blotch control

In a replicated small plot orchard experiment in 2003 a range of products was evaluated for control of sooty blotch (*Gloeodes pomigena*) in a mature organic Jonagold apple orchard at Oakwood Farm, Robertsbridge, East Sussex. Treatments were a programme of sprays of copper oxychloride, sulphur, kaolin or extract of coconut + citrus (Crop Life)+calcium carbonate applied on 4 occasions from late July to September using a mist blower at 1000 litres per hectare. None of the treatments controlled sooty blotch. The kaolin treatment whitened the trees and left an unsightly deposit on the fruits at harvest.

Objective 2. To identify 4-6 varieties of apple of low susceptibility to diseases that have high fruit quality, a range of seasons (storage potentials) and markets (dessert, culinary, processing) and are suitable for organic production:

Over 150 disease resistant apple varieties were evaluated by consortium partners, including Sainsbury's and Waitrose, for their suitability for organic production in the UK. Of these, the varieties Ceeval, Rajka, Resi, Rubinola and Rubinstep are recommended to growers. Although the variety Pinova performed consistently well in taste tests over successive years, the variety is not recommended due to its lack of disease resistance. The early season variety Discovery is recommended for non-supermarket sales only and the late-season variety Delorina is not recommended, but will, however, be retained for further evaluation, along with the popular European organic variety Topaz. All other varieties were considered to be of insufficient quality for supermarket sales.

Four culinary varieties (Edward VII, Encore, Howgate Wonder and Pikant) were found to be suitable for processing and also for fresh market sales. It is still too early to tell if these varieties are suitable for commercial organic growing, and ideally their agronomic performance needs to be evaluated on a larger scale. For organic juice production, varieties known to produce sufficient yields and volumes of juice (such as Fiesta, Red Falstaff) and are relatively easy to grow under organic protocols because of low susceptibility or tolerance to tolerance of diseases.

Valuable preliminary data on the pest and disease susceptibility, growth, habit, yield and storage requirements of the varieties evaluated were obtained.

Objective 3. To determine the activity (eradicant, protectant, antisporulant), persistence and efficacy of eight alternative organically acceptable fungicides for scab and mildew control

Experiments were conducted in glasshouse compartments or polytunnels to investigate the efficacy of several organic-compatible chemicals in controlling apple powdery mildew and apple scab when applied as a protectant, curative and antisporulant fungicide.

- Several products resulted in statistically significantly reduction of mildew or scab severity; however, the reduction in disease severity achieved by these products, compared to the untreated or fungicides, was very small and still unacceptable in commercial organic production.
- Only two traditional products, copper and sulphur, controlled scab and mildew effectively.
- We conclude that in the UK where environmental conditions are very conducive to scab and mildew epidemics, the only feasible solution to control scab and mildew in organic production is to grow cultivars which are resistant to the diseases, especially scab.

Objective 4. To determine and optimise the efficacy of six organically acceptable foliar spray treatments for control of rosy apple aphid:

- Sprays of *Quassia amara* extract, or the entomopathogenic fungus *Beauveria bassiana*, neem extract (azadirachtin), Garlic extract, of 2 novel botanical insecticides or of the standard treatments with potassium soap or rotenone did not control established rosy apple aphid colonies in spring. None of the products showed aphicidal properties in this situation.
- Control of rosy apple aphid by autumn applications of aphicides can be highly effective. Treatments with the conventional insecticides pirimicarb + cypermethrin or pirimicarb alone, which were included in field experiments as positive controls, were the most effective. Programmes of up to 3 sprays of these insecticides between late September and the end of October gave virtually complete control of rosy apple aphid.
- In one experiment, a single spray of pirimicarb + cypermethrin on 11 October 2001 gave 93% control whereas single sprays on 27 September or 25 October 2001 gave 34% and 70% control respectively, indicating early-mid October as being the optimum time of application in that year.
- Of the organically acceptable aphicides tested, pyrethrum (Py Insect Killer) was the most effective, programmes of 2-3 sprays in October giving 50-80% control.
- None of the other organically acceptable treatments tested in the autumn application experiments, potassium soap (Savona), rotenone (Derris), garlic extract (Envirepel), Kaolin (Surround), azadirachtin (Neemazal TS), natural plant extracts (Majestic) were sufficiently efficacious to provide a worthwhile degree of control of rosy apple aphid when applied in the autumn. Rotenone (Derris) and potassium soap were not effective as multiple sprays in admixture.

Key elements for successful organic apple production in the UK

Choice of site

Key requirements in order of priority

- Fertile, moisture retentive soil with good structure and drainage. Irrigation should be provided in drier areas.
- Low frost risk or frost protection.
- Good air circulation to reduce risk of disease.
- Freedom from pernicious perennial weeds.
- A 20m buffer zone from non-organic top or soft fruit crops is required by the Soil Association where there is a high risk of drift. Where the adjacent crops do not pose a high risk of spray drift, only a 10m buffer zone is required. If a sufficiently dense and tall intervening hedge or windbreak is present, no buffer zone is required.

Converting the site to organic status

The land on which organic crops are to be grown must be converted to organic status. For perennial crops (but excluding grassland), a period of 36 months from the last use of any material or practice not permitted in organic production must elapse before harvest of the first organic crop. Soil Association Certification (SA Cert) are able to issue a maximum 12 month reduction in the 36 month period providing that detailed management records and inspection of the site show that no prohibited practices have been used on the land in the requested backdate period. The use of non-permitted agrochemical and other practices must be stopped.

Choice of variety

Resistance to scab is very important and low susceptibility to mildew is highly desirable. For dessert production, the varieties Ceeval, Rajka, Resi, Rubinola and Rubinstep have been identified as suitable by this project. For culinary production, four culinary varieties, Edward VII, Encore, Howgate Wonder and Pikant, were found to be suitable for processing and also for fresh market sales. It is still too early to tell if these varieties are suitable for commercial organic growing, and ideally their agronomic performance needs to be evaluated on a larger scale. For organic juice production, varieties known to produce sufficient yields and volumes of juice (such as Fiesta, Red Falstaff) and that are relatively easy to grow under organic protocols because of low susceptibility or tolerance of diseases should be chosen.

Choice of rootstock

It is likely to be difficult to maintain excellent weed control in organic apple production, especially if on a large scale. Slightly more vigorous rootstocks than used in conventional production should be considered such as M26 on a very good deep soil or where irrigation is installed or MM106 or MM111 elsewhere. Newly bred rootstocks with potential for use in organic systems are under evaluation.

Site preparation

- Analyse the soil and correct the pH and any major nutrient deficiencies if necessary.
- Increase the organic matter content of the soil by applying manure or growing a green crop
- Eradicate problem perennial weeds as far as possible.
- Cultivate the soil to facilitate planting and establishment.

The above tasks can be done with conventional products prior to the start of conversion. However, if this is done, no backdating of the conversion start date is possible.

Planting system

A single row planting system should be used. Rows should be orientated to facilitate air drainage and circulation and harvesting. A wider row width than normal should be considered to encourage air circulation

Weed control

Achieving good weed control is likely to be one of the major challenges of organic apple growing and must be given a high priority. Dwarf apple trees are sensitive to competition from weeds for moisture and nutrients. The aim should be to maintain a weed free strip in the row with herbage in the alley. The optimum width of the weed free strip will depend on a number of factors including soil type, variety, row spacing and chosen method(s) of weed control. Lessons from conventional production suggest that for dwarf trees, a 1m wide strip is a practical option.

The methods of weed control that are to be used should be determined at the outset and necessary equipment purchased. The main options are as follows:

Infra red (IR) flame weeding
Direct flaming of weeds
Mulching with composted green waste
Mulching with plastics
Cultivation

Herbage in alleyway

A herbage alleyway should be established to maintain soil structure, host ground beetle predators of various pests and aid vehicle access. If this is not done, the alleyway will have to be cultivated regularly which is undesirable. Sow the alley in good conditions either before or after planting. The simplest option is to sow a dwarf, slow growing ryegrass mix. A tussocky grass mix may be chosen to provide a good habitat for ground beetles but this may be more costly and less hard wearing. White clover may be included to help fix nitrogen in the soil and increase fertility. It is also possible to include flowing plants in the mix that may provide a nectar source for hoverfly adults and other beneficial insects. However, certain species, notably

mayweed and other compositae are a good host for the common green capsid, which may be an important pest in organic apple production.

Nutrition

Apples have a moderately high nutritional requirement and it is difficult to maintain an adequate supply of N in organic production where use of conventional mineral fertilisers is not permitted. In organic production, priority should be given to the building and maintenance of soil structure and fertility by the planting of legumes, rotation, incorporation of green manures and the appropriate application and incorporation of composted farmyard manure. In practice, many of these approaches are inapplicable in a long-term perennial crop like apples and sources of farm yard manure are often not available locally.

Integrated pest and disease management(IPDM)

Key elements of a successful IPDM programme for organic apple production are summarised in Table S2 below

Table S2. Key elements of successful IPDM for organic apple production.

Pest/ disease	**Important IPDM methods**
Scab	• Choosing scab resistant varieties is vital • Encourage leaf rotting in the autumn by applying a high N foliar feed before leaf fall (Fish Oil or Nugro at 10x recommended rate) • Enhance leaf degradation in winter by mowing grass short and macerating leaf litter • Spray copper oxychloride before bud burst • Apply 2 further sprays of copper during green cluster
Mildew	• Choosing varieties of low susceptibility to mildew is important, especially in mildew prone areas • Remove all primary mildew infections as soon as they appear • Apply a full 10 day spray programme of sulphur from green cluster to the end of shoot growth. Higher volumes are preferable (1000 l/ha). Adjust the dose according to the mildew risk
Sooty blotch	• Ensure orchard has good air circulation. Effective spray treatments for sooty blotch need to be identified
Rosy apple aphid	• Apply 2-3 sprays of pyrethrum at 7 -10 day intervals starting at the end of the first week of October. High volume application (1000 l/ha) is likely to be more effective
Apple blossom weevil	• Plant new orchards with maximum spatial isolation from sources of infestation • Maintain nutritional status of trees so they produce high numbers of strong buds • Spray pyrethrum 1-2 times against adults around bud burst in spring
Codling moth	• Monitor with pheromone traps and sprays of granulovirus for control
Tortrix moth	• Monitor with pheromone traps and apply Bt to control hatching caterpillars

Technology transfer

Technology transfer activities which took place during the project are listed in the Table S3 below. Consortium meetings are listed in Table S4 and publications and reports are listed below.

Table S3. Technology transfer activities during organic apple LINK project

Date	Event/Activity	Input from project
6 April 2000	Organic workshop, HRI Wellesbourne.	Attended by J Cross.
20-21 July 2000	2 day study visit to organic apple growers in the Nor pas de Calais area of France.	Visit organised and lead by J Cross.
3 August 2000	Orchard Walk, Leighton Court, Herefordshire: Attended by 30 growers and crop advisors.	'Organic research at East Malling'. 20 minute talk given by J Cross.
11 October 2000	Welsh Pest management Forum: attended by 70 persons.	'Overview of Organic Pest, Disease and Weed control in fruit' ½ hour paper given by J V Cross
16-17 October 2000	International Organic Fruit Conference, Ashford International Hotel. Attended by > 100 delegates.	Lecture given by J Cross on IPM in organic apple production.
2 November 2000	Meeting of UK organic apple fruit group and site visit to organic apple farm, Snitterfield, Stratford-on-Avon. Approximately 20 specialists in organic production meet to formulate organic apple production guidelines.	Attended by J Cross, A Berrie, S Cubison and several consortium members.
22 November 2000	EMRA Organic Top Fruit Production Day at East Malling Research attended by >100 delegates including many growers.	Talk on 'Identifying suitable apple varieties for organic production' by S Cubison.
29-30 November 2000	Meeting of European Group of Organic Fruit Researchers (EUGROF) at FiBL, Frick, Switzerland.	Presentation of 'Organic Fruit Research in the UK' by S Cubison.
18 March 2001	Meeting of UK organic apple fruit group and site visit to organic apple farm, Little Pattenden, Marden. Approximately 20 specialists in organic production meet to formulate organic apple production guidelines.	Attended by J Cross, A Berrie, S Cubison and several consortium members

13 July 2001	Defra review of organic research.	Presentation of project given by A Barlow and J Cross.
11-12 Dec 2001	Forum National Fruits et Legumes Biologiques, Bouvines (Nord), France. (Interreg Transborder Conference).	Paper by T.Webster and talk given by S Cubison on suitable apple and pear varieties for organic production.
4-7 Feb 2002	10th International Conference on Cultivation Techniques in Organic Fruit and Vine production, Weinsburg, Germany.	Poster presentation by S Cubison on 'Organic Fruit Production Research in the UK.'
27 Feb 2002	Waitrose Organic Workshop, Leckford Estate, Leckford, Hants. Attended by Waitrose growers.	Presentations on Pest, Disease and Weed control in fruit given by A. Berrie, J.Cross and S Cubison.
25 June 2002	Horticulture LINK User Workshop, HRI-W.	Attended by J Cross.
22 August 2002	EMRA top fruit conference. 'Organic top Fruit: The market and Production Research'. Attended by 80 persons.	Full days EMRA conference on organic top fruit production where all the work in the LINK project was reported.
9 October 2002	Highly commended in Worshipful Company of Fruiterers Organic Achievement awards.	Award received by J Cross and S Cubison from the Lord mayor of London.
2-3 Dec 2002	2nd Meeting of European Group of Organic Fruit Researchers (EUGROF) at FiBL, Frick, Switzerland.	Update on 'Organic Fruit Research in the UK' by S Cubison.
18 February 2003	FAST top fruit conference attended by 70 growers.	'Novel approaches to pest and disease control'. ½ hour talks given by J Cross and A Berrie on autumn control of rosy apple aphid and scab.
22 October 2003	National Fruit Show, Detling, Kent 2 hour seminar on organic apple LINK project attended by 50 persons.	Lectures giving full report of project given by A Barlow, J Cross, A Berrie, S Cubison followed by discussion.
27 February 2004	Horticulture LINK in Focus: Programme review and Grower of the year awards, Lancaster Gate Hotel.	Presentation of Overview of organic apple LINK project made by A Barlow. Poster provided.
20-22 April 2004	BGS/AAB/COR Conference 'Organic Farming' – Science and practice for profitable livestock and cropping.	Paper and talk given on 'Varieties and Integrated Pest and Disease Management in the UK'

		given by S Cubison.
16 June 2004	Soil Association workshop 'Organic Top Fruit Production and Orchard Conversion' at Oakwood Farm, Roberstbridge attended by 30 growers and technologists.	½ hour talks given by S Cubison, C Firth and J Cross on varieties and rootstocks, pest and disease control and economics respectively.
4 November 2004	EMRA Top Fruit Crop Protection day at East Malling Research	½ hour lecture on 'Autumn control of rosy apple aphid' given by S Cubison
11 November 2004	Meeting between A Barlow & Defra	A Barlow met with R Fransella, P Crofts, R Unwin, F Salaun and M Bell to discuss the project and its achievements and future research.
6-9 January 2005	Soil Association Annual Conference, Newcastle University.	Talk on 'Varieties and Integrated Pest and Disease Management in the UK' given by S Cubison.
3 February 2005	Conference in East Malling Conference Centre ' Organic apples: from production to marketing'.	½ hour lecture given by J Cross reporting the results of the organic apple LINK project and talk on varieties by S Cubison.
9 February 2005	British Independent Fruit Growers Annual Conference, Bewl Water Conference centre.	½ hour talk given by J Cross on autumn control of rosy apple aphid.

Table S4. Consortium meetings and site visits held during project

Date	**Venue**	**Meeting/Activity**
31 July 2000	EMR	First consortium meeting
6 Sept 2000	Oakwood farm, Roberstbridge	Site visit
22 Nov 2000	EMR	Second consortium meeting
13 Feb 2001	EMR	Third consortium meeting
13 June 2001	North Court fruit farm, Old Wives Lees	Site visit
14 November 2001	EMR	Fourth consortium meeting
6 March 2002	EMR	Fifth consortium meeting
12 June 2002	Oakwood Farm, Roberstbridge	Site visit
12 November 2002	EMR	Sixth consortium meeting
12 March 2003	EMR	Seventh consortium meeting
30 July 2003	North Court fruit farm, Old Wives Lees	Site visit
12 November 2003	EMR	Eighth consortium meeting
10 March 2004	EMR	Ninth consortium meeting
21 July 2004	Field trials at Oakwood farm, EMR and North Court	Site visits
17 November 2004	EMR	Tenth consortium meeting
17 March 2005	EMR	Eleventh consortium meeting
13 July 2005	EMR	Twelfth consortium meeting

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Intended future publications

Cross, J. V. Berrie, A. M., Cubison, S., X, Firth, C. Integrated Pest and Disease Management for organic apple production in the UK. To be submitted to International Journal of Pest Management.

Cross, J V. & Cubison, S. Autumn treatment for rosy apple aphid control in conventional and organic apple production. To be submitted for publication in Crop Protection.

Xu & Berrie, A. M. 2005. Efficacy of alternative chemical tr4eatments against apple scab and mildew. Proceedings of IOBC IPP fruit crops working group 'Orchard Diseases' sub group workshop, Italy, August 2005. IOBC bulletin.

Reports

Cross, J, Webster, T, Berrie, A. M. Xu, X, Firth, C, Knight, S. 2001.Varieties and Integrated Pest and Disease Management for Organic Apple Production LINK project HL0150LOF Report 1 issued 17 January 2001, 42 pp.

Cross, J, Webster, T, Johnson, D, Berrie, A. M. Xu, X, Firth, C, Knight, S. 2002.Varieties and Integrated Pest and Disease Management for Organic Apple Production LINK project HL0150LOF Report 2 issued 2 January 2002, 64 pp.

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Cross, J, Johnson, D, Berrie, A. M. Xu, X, Firth, C, Knight, S. 2005.Varieties and Integrated Pest and Disease Management for Organic Apple Production LINK project HL0150LOF Report 5 issued 11 March 2005, 72 pp.

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Future exploitation of results

- A SOLA has been obtained already for the use of Pyrethrum by growers to control Rosy Apple Aphid and Apple Blossom Weevil, resulting from the research findings of the Project.
- The "Practical Notes for Growers", which summarise the findings from the project will be sent to marketing organisations and growers' co-operatives.
- Renaming of recommended varieties, where possible and considered necessary, will be undertaken before the end of 2005 to make the varieties more attractive to consumers.
- The recommended varieties will be advised to growers for new or replacement plantings by Waitrose and Sainsbury's. From 1st September, the recommended varieties will be discussed with all other multiples by Adrian Barlow and tastings arranged when sufficient fruit is available with the intention of ensuring all major retailers list the recommended varieties and encourage their suppliers to plant them.
- An existing orchard is being grafted with some of the new varieties by an organic apple grower in Kent. Results will be monitored and reported to the industry through grower meetings and press articles.
- A 3ha organic orchard will be planted with the recommended varieties at EMR in the autumn of 2005 which will be expanded to 15ha in subsequent years. This will be used to undertake further research on maximising fruit quality and determining best storage regimes. Results will be reported to the industry through grower meetings and trade press articles.
- A seminar will be held at the National Fruit Show 2005 to summarise the findings and conclusions of the research and to highlight the recommended varieties.
- Many of the conclusions arising from the project have already been incorporated into the "Best Practice Guide for Apple Production" and the remainder will be added when the Guide is next revised.
- The results and conclusions of the Project will be sent to the Soil Association and the other organic certification bodies.

Factors limiting the performance of organic apple production in UK have been reviewed and proposals for further research have been submitted to DEFRA

Milestones – (revised Nov 2002)
(Milestones given in bold are primary milestones)

No.	Due date	Milestone (progress target)
1.1	30/04/00	Experimental approval for CpGV and Quassia applied for. ✔
1.2	30/04/00	Experimental protocols established for IPDM trials and trials laid out. ✔
1.3	30/04/00	Varieties chosen and ordered for site 2. ✔
2.1	30/04/00	Selection criteria for preliminary variety screen determined. ✔
3.1-3	30/04/00	Protocols formulated and potted trees and products for glasshouse scab/mildew tests acquired. ✔
4.1-3	30/04/00	Protocol formulated, products acquired and site selected for first rosy apple aphid orchard experiment. ✔
3.4	30/06/00	First glasshouse scab experiment completed. ✔
4.4	31/07/00	Firsts rosy apple aphid experiment completed. ✔
1.8-10	30/09/00	Treatment applications and assessments at site 1 in first season completed. ✔
1.1	30/09/00	Exp. approval for CpGV and Quassia obtained. ✔
1.11	30/09/00	Farm walk at site 1 occurred. ✔
2.2	30/09/00	Data base for candidate varieties created. ✔
3.5	30/09/00	First glasshouse mildew experiment completed. ✔
2.4	30/11/00	Preliminary taste & processing tests completed. ✔
1.12-13	31/12/00	Economics of IPDM at site 1 in year 1 determined. Strengths and weaknesses identified. ✔
2.5-7	**31/12/00**	**20 most promising apple varieties short-listed.** ✔
3.8	**31/12/00**	**Preliminary evaluation of fungicides for scab and mildew control in the glasshouse completed.** ✔
4.5-7	**31/12/00**	**Results of first rosy apple aphid experiment evaluated. Active products for direct control identified.** ✔
2.8	31/01/01	Bud-wood of 20 short-listed varieties obtained and grafted. ✔
1.7	**31/03/01**	**Experimental IPDM orchard planted at site 2.** ✔
3.9-10	30/04/01	Protocols formulated and potted trees and products for second years glasshouse scab/mildew tests acquired. ✔
3.11	30/06/01	Second glasshouse scab experiment completed. ✔
4.8-10	30/06/01	Protocol formulated, products acquired and site selected for second rosy apple aphid orchard experiment. ✔
1.8-10	30/09/01	Treatment applications and assessments at sites 1 and 2 in year 2 completed. ✔

✔ = completed in full and on time ‡see note on p 25
Note: milestones in bold are primary milestones

No.	Due date	Milestone (progress target)
1.11	30/09/01	Farm walk at site 2 occurred. ✔
3.12	30/09/01	Second glasshouse mildew experiment completed. ✔
3.15	**31/12/01**	**Most promising products for scab and mildew control identified.** ✔
3.16-17	31/02/02	Protocol established and site selected for scab/mildew control orchard experiment in year 3. ✔
2.10-11	**31/03/02**	**Replicated variety experiment at East Malling planted.** ✔
4.13-15	**31/03/02**	**Results of second rosy apple aphid experiment evaluated. Active products for control in autumn identified.** ✔
4.16-17	31/03/02	Protocol established and site selected for rosy apple aphid control orchard experiment in year 3. ✔
1.14	30/04/02	Draft handbook for IPDM in organic apple production produced. Results to date reported at EMRA members day. ✔
1.8-10	30/09/02	Treatment applications and assessments at sites 1 and 2 in year 3 completed. ✔
2.12-13	30/09/02	Sulphur spray programme applied and pest and disease levels assessed on variety experiment at East Malling in year of establishment. ✔
Old‡		
3.18	30/10/02	Orchard experiment evaluating active fungicide products at full dose and volume completed.
New‡		
3.18	30/10/02	Sand-bed experiments evaluating active alternative products at full dose and volume against scab and mildew completed. ✔
1.12-13	31/12/02	Economic performance of IPDM programme at sites 1 and 2 in year 3 determined. Strengths and weaknesses identified ✔.
1.15	**31/12/02**	**Performance of preliminary IPDM programme on disease susceptible and disease resistant cultivars at two sites determined.** ✔
2.14	**31/12/02**	**Variety trial at East Malling established.** ✔
2.15	31/12/02	Taste tests on fruit for varieties available in year 3 done. ✔
1.16	**28/02/03**	**Refined IPDM programme formulated.** ✔
4.18-20	**31/03/03**	**Results of third rosy apple aphid experiment evaluated. Most promising timing(s) identified.** ✔

✔ = completed in full and on time ‡see note on p 25
Note: milestones in bold are primary milestones

No.	Due date	Milestone (progress target)
4.16-17	31/03/03	Protocol established and site selected for rosy apple aphid control orchard experiment in year 4. ✔
1.17-19	30/09/03	Refined IPDM programme applied and assessments at sites 1 and 2 in year 4 completed. ✔
1.20	30/09/03	Third growing season farm walk occurred. ✔
Old‡		
3.19	30/10/03	Orchard experiment evaluating best fungicide product(s) at range of doses and spray intervals completed.
New‡		
3.19	30/10/03	Sandbed experiment evaluating the combination of best alternative product with bud-burst copper completed. ✔
3.20	30/10/03	Orchard experiment evaluating the efficacy of bud-burst copper spray at various doses completed. ✔
2.16-17	30/11/03	P&D susceptibility and agronomic performance of varieties in experiment in first cropping year determined. ✔
1.21-22	31/12/03	Economic performance of refined IPDM programme at sites 1 and 2 in year 4 determined. Strengths and weaknesses identified. ✔
2.18	**31/12/03**	**Taste and processing tests on varieties in trial done.** ✔
4.18-20	**31/03/04**	**Results of fourth rosy apple aphid experiment evaluated. Most promising dose and application method identified.** ✔
4.16-17	31/03/03	Protocol established and site selected for final rosy apple aphid control orchard experiment. ✔
1.17-19	30/09/04	Refined IPDM programme applied and assessments at sites 1 and 2 in year 5 completed. ✔
1.20	30/09/04	Fourth growing season farm walk occurred. ✔
Old‡		
3.20	30/10/04	Orchard experiment evaluating best fungicide product(s) repeated to validate results.
New‡		
3.21	30/10/04	Orchard experiment evaluating best strategies for managing scab and mildew completed. ✔
2.16-17	30/11/04	P&D susceptibility and agronomic performance of varieties in experiment in second cropping year determined. ✔
1.21-22	31/12/04	Economic performance of refined IPDM programme at sites 1 and 2 in year 5 determined. Strengths and weaknesses identified.

✔ = completed in full and on time ‡see note on p 25
Note: milestones in bold are primary milestones

No.	Due date	Milestone (progress target)
1.24	**31/12/04**	**Performance of preliminary IPDM programme on disease susceptible and disease resistant cultivars at two sites determined.** ✔
2.18	**31/12/04**	**Taste and processing tests on varieties in trial done on fruit from second cropping year.** ✔
3.24	**31/12/04**	**Most effective alternative fungicide treatment for scab and mildew control determined.** ✔
4.20-22	**31/12/04**	**Best treatment for rosy apple aphid identified.** ✔
1.20	29/02/05	Results of work reported at EMRA members day.
2.19	29/02/05	Preliminary storage tests complete. ✔
1.23	**31/03/05**	**IPDM programme fully developed. Grower handbook on IPDM in organic apple production produced. Results of IPDM trials prepared for publication in refereed journal.** ✔
2.22	**31/03/05**	**4-6 apple varieties for organic apple production identified.** ✔
3.22-23	**31/03/05**	**Results of fungicide evaluations written up and prepared for publication in a refereed journal. Registration of best treatment by parent company fostered.** ✔
4.21-22	**31/03/05**	**Results of evaluations of products for control of rosy apple aphid evaluations written up and prepared for publication in a refereed journal. Registration of best treatment by parent company fostered.** ✔

✔ = completed in full and on time ‡see note below
note: primary milestones are given in bold

‡Amendment of milestones 3.18, 3.19 and 3.20

These milestones were amended in agreement with the consortium because the first two years results did not identify any promising alternative chemicals for field trialling

Objective 1a. To evaluate and refine an innovative Integrated Pest and Disease Management (IPDM) programme for organic apple production in the UK

INTRODUCTION (OBJECTVE Ia, FINAL REPORT)

Since the 1990s, consumer demand for organic apples in the UK has increased. This demand is expected to continue to rise, yet over 90% of current supplies are imported. The volume of UK production is currently very small and totally inadequate to meet the rising demand. Current methods of organic apple production are unsatisfactory with low yields and erratic and quality poor. Pest and disease problems are one of the main reasons for this poor performance. The aim of this investigation was to develop, evaluate and refine Integrated Pest and Disease Management (IPDM) programmes for organic apple production in the UK based on organically-acceptable control approaches at two sites representing two contrasting scenarios in which it is considered that organic apples will be produced in future. One is the situation where established orchards, normally of disease susceptible varieties and conventional planting systems, would be converted to organic production. The other is the situation where a new orchard is established as the land is converted to organic status, providing the option for varieties and the planting system to be selected specifically for organic production.

Several studies reporting the results of field experiments investigating the performance, including economic aspects, of organic apple production systems including Integrated pest and Disease Management are reported in recent literature (e.g. Delate and Friedrich, 2004; Stockert, 2000; Schmid et al, 1997; Zurcher et al, 2003; Friedrich et al, 2003; Waibel et al, 2001; Groot, 2000; Swezey et al, 1998). Results appear to have been mixed but several studies have concluded that higher prices for organic apples can compensate for losses in yield and quality. Successful organic apple production relies on effective methods of managing the most damaging pests and diseases of apple including apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leuchotricha*), rosy apple aphid (*Dysaphis plantaginea*) and codling moth (*Cydia pomonella*). Several other pests and diseases, which are of minor importance in conventional apple production are potentially very damaging in organic production where synthetic pesticides cannot be used to control them.

Here we report the results of two field experiments, one in a converted orchard the other in a purpose planted organic orchard, investigating the performance of organic IPDM programmes. At the outset, a prototype programme was used based on existing knowledge and experience. This programme was refined during the experiment in the light of results obtained.

METHODS AND MATERIALS (OBJECTVE 1a, FINAL REPORT)

Two large-plot field experiments to develop and evaluate improved methods of Integrated Pest and Disease Management for organic apple production were done, one investigating each of the two scenarios described above.

Sites, orchards and varieties

Experiment 1. Conventional orchard of a disease susceptible variety converted to organic: The whole of an existing 1.4 ha apple orchard cv Fiesta with *Malus* pollinators at Oakwood farm, Robertsbridge, East Sussex which was planted as a conventional orchard in 1994 using MM106 rootstocks. Conversion to organic status started in 1997 and took 3 years as required by organic production rules. Fiesta is a variety that is known to be highly susceptible to scab and moderately susceptible to mildew. The row spacing was 4.95 m and the spacing between trees in the row is 3.3 m.

Experiment 2. Purpose planted organic orchard new apple orchard of a chosen resistant and a low disease susceptibility variety: A new apple orchard in 'Lower Profits' field (1.6 ha), North Court Fruit Farm, Old Wives Lees, Canterbury. Kent was originally planted with bench grafted trees of a range of 8 disease resistant varieties on 8 May 2000. However, these made very poor growth in both 2000 and 2001. It was grubbed and replanted with well-grown, feathered organically certified nursery trees of two varieties: Pinova (from the Netherlands) in December 2001 and Topaz from Italy in March 2002. Pinova was believed to be of low to moderate susceptibility to scab and mildew. It was chosen because of its low susceptibility and because it was known to have good fruit quality with long term storage potential. Topaz, a scab resistant variety bred with the single Vf resistance gene from *Malus floribunda*, was chosen because of its resistance to scab, low susceptibility to mildew, good growth characteristics and popularity for organic production in other Northern and central European countries. The whole planting comprised alternating pairs of rows of the two varieties. The row spacing: was 4.0 m and the spacing between trees in the row was 2.2m.

Treatments

Treatments evaluated in the two experiments were as follows:

Experiment 1

A1. Experimental IPDM programme
A2. Grower’s organic pest and disease control programme
A3. Untreated control

Experiment 2

A1. Experimental IPDM programme
A3. Untreated control

Components of the IPDM programmes

Approaches followed for control of the major pests and diseases at the two sits were as follows:

Scab: To minimise the amounts of overwintered scab inoculum on leaves, leaf litter was destroyed by maceration after leaf fall and before bud-burst. Any wood scab was

removed during winter pruning as far as possible. Except in the first year, a spray of copper oxychloride (5 kg of Cuprokylt in 1000 l water/ha) was applied at bud-burst. In the final 2 years of experiment 1 and the final year of experiment 2, additional sprays of copper (50 l of Wetcol 3 in 100 l water/ha) were applied after bud burst and before flower to try to improve scab control. In the early years of experiment 1, an intensive programme of sprays of micronised sulphur was applied for scab control starting from bud-burst. The rates used varied starting initially with the same low rate used by the grower (3.6 kg a.i. /ha) but in 2001 and 2002 the rate was increased to 9 kg a.i. /ha in an attempt to improve control. In the fourth year, because the strategy was ineffective for scab control, the number of sprays applied was greatly reduced (to 2 sprays) and the rate of application reduced to 4 kg a.i. /ha. In the final year, the number and rate of sulphur sprays was restored because they were found to be important for adequate mildew control (see below).

Mildew: Trees in the IPDM plots were inspected carefully during flowering and at petal fall and all primary blossom or vegetative mildew were removed As described above, a programme of sprays of sulphur was applied starting from shortly after bud-burst.

Apple blossom weevil: No treatments were applied for apple blossom weevil in the first year of experiment 1. However, in the second year a spray of pyrethrum (10 l Py insect Killer/ha) was applied to the IPDM plots in an attempt to control adults before significant egg laying has occurred. No treatment was applied to the growers or the untreated plots in that year. The number of sprays of pyrethrum was increased to 2 in the IPDM plots in the 3rd, 4th and 5th years of experiment 1. The grower attempted to control blossom weevil with 2 sprays of Derris in the third year of the experiment (2004). As this was unsuccessful, he applied 1 spray of pyrethrum to his plots in the final two years of experiment 1. Apple blossom weevil was not seen in experiment 2 and no sprays were applied for control of apple blossom weevil. However, in the final year of experiment 2, two early season sprays of pyrethrum were applied to the IPDM plots at the green cluster growth stage against rosy apple aphid.

Tortrix moth and winter moth caterpillar control: Sprays of *Bacillus thuringiensis* were applied for caterpillar control in the IPDM plots in all years but the third in experiment 1 and in the last year only in experiment 2. Multiple sprays were applied in the first years of experiment 1 but numbers of spray applications were reduced subsequently because it was not clear any benefit was being obtained.

Codling moth: Four sprays of codling moth granulovirus (Carpovirusine) were applied to the IPDM plots in the first year of experiment 1 and two sprays in the second and third years. Each year, the first spray was applied approximately 10 days after the first above threshold catch (> 5 moth/trap/week) of adult codling moth in the sex pheromone trap sited in the centre of the trial area. Subsequent sprays were applied at 10-14 day intervals. However, no granulovirus sprays were applied in the final two years of experiment 1 because no codling moth damage dad occurred in any of the previous years and continued use seemed not to be worthwhile.

Other IPDM treatments: Artificial bottle refuges were provided for earwigs and other predators in every tree in the IPDM plots in experiment 1. For fruit tree red spider mite and apple rust mite was not expected to be a problem in this experiment because

the predatory phytoseiid mite *Typhlodronus pyri* was well established throughout the orchard. Other treatments envisaged for the IPDM treatments included application of sprays of potassium soap (Savona) against rosy apple aphid, application of sprays of extract of Quassia (Bitrosan) for apple sawfly at petal fall, physical destruction of woolly aphid colonies. However, the soap sprays separate trials showed that they were ineffective and in any case, rosy apple aphid was not a problem in experiment 1 except in year 1. In experiment 2, 2 early season sprays of pyrethrum were applied for rosy apple aphid control in experiment 2 in the final year (2004). Other treatments envisaged were not applied because none proved necessary because significant outbreaks of the target pests did not occur.

Experiment designs

Experiment I: A randomised block design with three replicates was used. The treated plots were 6 rows wide and ran the whole length of the orchard (Figure 1.1). However, all assessments were done on a sub-plot of 20 trees (two adjacent sets of 10 trees) in the central two rows of the plot. This was to minimise the effects of spray drift contamination from adjacent plots. The location of the sub-plots in the rows was chosen to avoid areas of weak growth caused by water-logging. The IPDM and the grower's plots were kept in the same locations throughout the duration of the experiment. However, each year except the last year, the unsprayed plots were moved to new locations at the ends of three of the treated plots and were six rows wide by 6 trees long (see Figure 1.1).

Experiment 2: A randomised design with four replicates of two treatments, the experimental IPM programme versus an untreated control, was used (Figure 1.2). Plots were at least 8 rows wide and contained 2 pairs of rows of each of the two varieties, Topaz and Pinova. Assessments were done on the central 2 rows of each variety in each plot.

Assessments

Diseases: In April, at the pink bud to early flower growth stage, the incidence of overwintered leaf litter on the surface of the ground in each plot in experiment 1 was assessed using the point transect method. The number of points out of 100 at which leaf litter was found in each plot was determined. In 2000 (but not in subsequent years) at the start of the experiment, a sample of leaf litter was analysed for scab spores (ascospores) using the method of Hutton & Burchill (1965). On the same day, a general visual inspection of each of 10 trees in the central sub-plot of each plot were made for the presence or absence of scab on the whole tree. The incidence of primary blossom mildew, scab and any other diseases were also assessed by examining 400 blossom trusses per plot. In summer shoot mildew (using the method of method of Butt & Barlow (1979)) and scab and any other diseases were assessed on a sample of 50 growing shoots per plot. At harvest in early to mid September each year, the percentage fruits infected with scab, was assessed on a sample of up to 1000 fruit per plot (see below). The severity of sooty blotch infection on the skin each individual fruit of a random sample of 100 fruits per plot was scored into categories of severity (none, slight, moderate, severe). The number of fruits in each category was calculated. Just pre leaf fall on 14 October, a sample of 100 leaves was taken from each plot for assessment for levels of late scab infection. The samples were stored in a fridge until

they were assessed in November. The degree of infection on each leaf was scored into none, slight, moderate and severe categories. The percentage leaves infected was calculated.

Pests: Full pest assessments were done on each plot in April (green cluster –pink bud) and May (post blossom – early fruitlet). General inspections of the plots were made in June, July and August and additional full pest assessments were done as necessary if new pest or damage was present to a sufficient degree to justify a full assessment. For the two full pest assessments, 20 trees (in the central sub- plot) were assessed per plot. For the first assessment, the numbers of trusses per tree infested with rosy apple aphid were counted. Five trusses per tree were examined closely for the full range of pests and damage including capsid, tortrix and winter moth, rosy apple and apple grass aphid, apple sucker and apple blossom weevil adults. The same general method was used on 28 May but the number of flowers with apple blossom weevil larval damage (capped blossoms) and the number parasitised by *Scambus pomorum* were also counted so that the percentage larvae parasitised could be calculated.

The incidence of damage caused by pests on fruits was also assessed at harvest (see below).

Codling moth and tortrix moth adults: One pheromone trap (standard delta design) for each of the three main pest species (codling moth, fruit tree tortrix moth (*Archips podana*) and summer fruit tortrix moth (*Adoxophyes orana*) was set in the centre of the experimental orchard at site 1 on 28 May 2003. The number of male moths of each species was recorded at approximately weekly intervals from early may to End of August.. Lures were renewed at 4-6 week intervals. Sticky based were renewed as frequently as necessary.

Nutritional status: A sample of 50 leaves, selected from the mid-point of the current seasons extension growth, was taken from each treatment (i.e. overall from 3 plots) in August each year and subjected to standard leaf mineral analysis in the laboratory. A sample of 15 fruits of approximately 60mm diameter was taken from each treatment (combining 5 fruits from each plot for that treatment) for mineral analysis at harvest each year.

Yield and quality at harvest: In experiment 1 at harvest in early to mid September each year, all the fruits on 10 trees in the central sub-plot of each plot were harvested. The total number and weight of fruit on each tree was recorded. The fruit from each plot was then separated into Class I, Class II, Class ill (Juice) and outclass quality grades. A lower size threshold for the Class I quality grade of 60 mm was applied. Discoloration due to sooty blotch infection (which was present on the surfaces of a large proportion of the fruits). The total weight of fruit in each quality grade was recorded for each plot. Each fruit was then individually examined for blemishes due to each pest and disease and the number and weight of fruit damaged by each recorded. Many fruits had blemishes caused by two or several pests and diseases and each was recorded. In the first year in experiment 2 (2002), too few fruits were present for assessment of yield and quality. In the subsequent two years the total number and weight of fruits from 10 trees per variety per plot was recorded. Assessments of the incidence of blemishes was done on the fruit that was sampled in the same way as in experiment 1.

Economic analysis: The total and marketable yields from treatments were multiplied by current organic apple prices (e.g. £1.20/kg for a combined Class I&II and £150/t for juice). The total financial output for each plot was calculated and compared with typical organic outputs obtained from a previous study (Firth, 1999) and with typical yields and financial outputs which could have been obtained if the orchard had remained in conventional production. The five years data from experiment 1 were also compared. The costs of the three spray programmes are also determined for comparison purposes and these are related to their relative financial output. All other costs of production (direct and overheads costs) were modelled in to arrive at estimated net margins per hectare and per kilogram of fruit grown.

Statistical analysis

Where appropriate, results were subjected to analysis of variance followed by mean separation using a LSD test. A cross year analysis was not appropriate because of differences between the treatments in the different years and because, in experiment 1, the untreated controls were moved to new locations each year except the final year. Means which did not differ significantly (P=0.05) are given the same letter in the results tables.

RESULTS (OBJECTVE Ia, FINAL REPORT)

Scab

In Experiment 1, in 2000, analysis of leaf litter sampled from the orchard indicated a high incidence of overwintering scab (2500-6800 scab ascospores/ml) and a high potential scab risk. Weather in April and May 2000, the critical period for scab infection, was wet and favoured scab infection and development with high numbers of scab periods (based on ADEM) recorded (Table 1a.3). The programme of 15 sulphur sprays applied to both experimental and grower plots was only slightly effective in controlling scab. The disease was first recorded on 27 April (pink bud) at low incidence on most trees. By May 92-100% of trusses were infected with scab (Table 4), most being recorded on untreated plots. At harvest 50-60% fruit was scabbed in treated plots compared to nearly 90% in untreated plots, indicating that the sulphur programme had given some control of the disease. . There was a high incidence of late leaf scab recorded in November (Table 1a.4) indicating a high scab risk for 2001. However, in 2001, apart from a significant number of scab periods (Table 1a.3) around bud burst, the weather from green cluster to petal fall was relatively dry and low risk for scab. Scab was first observed during bloom with 3.3% of trees with scab in the experimental plots compared to 30-37% in the grower and untreated plots (Table 1a.4). These treatment differences continued through the season with the least scab recorded on experimental plots and similar levels recorded on the grower and untreated plots. The low scab incidence compared to that in 2000 reflects the low risk scab year. The application of copper to the experimental plots pre bud burst combined with the use of a higher rate of sulphur accounts for the better scab control in this treatment. In spring 2002 there was a high incidence of overwintering leaf litter remaining in the orchard in the early spring. The incidence of late leaf scab recorded in 2001 (up to 60% infected leaves) meant that the leaf litter had a high scab

ascospore potential and hence a high scab risk. 2002 was a high scab risk season with significant scab periods recorded at bud burst and during blossom and early fruitlet (Table 1a.3). The copper spray applied pre bud burst to experimental plots was sufficient to give some scab control pre bloom resulting in a lower scab incidence on rosette leaves and fruit (77%) (Table 1a.4) compared to the grower and untreated plots where almost all fruit were scabbed at harvest. However, the benefit of the early copper spray was soon lost post bloom where the wet weather favoured scab infection resulting in 90-100% infected shoots and no difference between treatments. The high incidence of late scab on leaves assessed in November indicated a potential high scab risk for 2003.. Spring 2003 was exceptionally dry pre bloom and the first scab period was not recorded until 24 April. This combined with the low incidence of leaf litter in the orchard meant that scab was not recorded in the trial until June (Table 1a.4). The two applications of copper applied in early spring resulted in a 50% reduction in scab incidence on shoots in June and July, although by September there was no difference in scab incidence on shoots. At harvest the incidence of scabbed fruit was lowest in the experimental plot (6.6%) compared to 23-36% scabbed fruit in untreated and grower plots. Again there was a high incidence of late scab on leaves assessed in November indicating a potential high scab risk for 2004.. Weather in spring 2004 was very favourable for scab. The scab incidence recorded on fruit trusses in May (Table 1a.3) was considerably lower on the experimental plots indicating the copper sprays applied up to mouse ear had given reasonable control of scab on rosette leaves and fruit. This was also reflected in the higher yield and number of fruit on the trees in the experimental plots and the lower incidence of scabby fruit at harvest (Table 1a.4).Because of the continued high risk scab weather in May and June, the early differences in scab incidence on the plots were soon lost such that by the July assessment scab incidence on shoots was high for all plots As in previous years the incidence of late leaf scab \assessed in November was high.

In experiment 2, in 2002, which was a high risk scab season, no scab was recorded on the variety Topaz (Vf scab resistance). However, at the first assessment in May scab was present on nearly half the trees of the variety Pinova in untreated plots and over 80% shoots assessed in June (Table 1a.5) and 100% fruit at harvest. Scab incidence was less on treated plots which had been sprayed with Sulphur, but still unacceptably high.. Spring 2003 was exceptionally dry and no scab was found on the trees until early May. No scab was recorded on the Topaz trees pre harvest, but 2% of leaves were infected with late scab when assessed in October. The incidence of scab on the Pinova was considerably reduced compared to 2002, reflecting the lower risk scab year (Table 1a.3) and the early application of copper. More than 25% shoots were infected with scab in July with little difference between treated and untreated. The incidence of scab on fruit at harvest was very low (1-5%). However, wetter conditions in late summer resulted in a high incidence of late leaf scab. Weather in spring 2004 was very favourable for scab. A low incidence of scab was recorded on shoots in July on treated and untreated plots, around 1%., but no scab was recorded on fruits at harvest. By contrast, scab was recorded on 75% of shoots of Pinova in untreated plots in July with over 30% of fruits scabbed at harvest. The additional early sprays of copper reduced scab incidence on treated plots but still resulted in 20% of fruit scabbed at harvest.

Mildew

In experiment 1, the incidence of primary blossom (Table 1a.6) and vegetative mildew remained consistently low, even in plots where moderate to high levels of secondary infection occurred the previous season. The primary infections were removed each year when they became visible, but after the assessments had been done. The low incidence of primary infection in experiment 1 appeared to be related to the site or location of the experiment which was seemingly in a low mildew risk area. In areas of high mildew risk, the variety Fiesta is known to develop high levels of primary mildew when adequate controls are not applied.

In the first year (2000), the experimental and grower's treatments had received the same programme of sulphur sprays for mildew control, though the sprays to the experimental plots were applied at 1000 l/ha whereas the sprays to the grower's plots were applied at 125 l/ha. Secondary mildew infection was significantly reduced compared to the untreated control for both treatments (Table 1a.6), especially on the experimental plots where the higher volume sprays had been applied. In the second and third years (2001 and 2002), the rate of sulphur application was increased on the experimental plots (in an attempt to improve scab control). Secondary mildew levels for this treatment were very low, both at the June-early July and July – August assessments. However, they were not significantly lower than the grower's plots. In the final 2 years (2003 and 2004), use of sulphur was abandoned by the grower (because he did not perceive substantive benefit from sulphur sprays for scab control). In the first of these two years only 2 sprays of sulphur at the low rate of 4 kg a.i. /ha were applied to the experimental plots. Mildew levels were high in the grower's and untreated plots and markedly (and significantly) lower in the experimental plots, though still greater than they had been in 2001 and 2002. In the final year (2004), the number and rate of sulphur sprays to the experimental plots was restored to those applied in 2002 and 2002. Mildew levels were very high on the untreated and the grower's plots and markedly and significantly lower on the experimental plots. However, the levels were higher than in 2001 and 2002, presumably because weather conditions in 2004 were especially favourable to mildew.

Experiment 2 was located in an area more prone to mildew. The variety Pinova proved to be highly susceptible to mildew, Topaz moderately susceptible. In the first two years (2002 and 2003), only 2-3 sprays of sulphur for mildew control were applied at 8 kg a.i. / ha in 2002 and at the low rate of 3.2 kg a.i. /ha in 2003. The incidence of primary mildew was low in spring 2002 but increased markedly in 2003, on both varieties but especially on the Pinova (Table 1a.7). The incidence was lower on the experimentally treated plots than on the untreated plots. Secondary mildew levels were high, reaching virtually 100% of shoots infected on Pinova in late July-August. Levels were lower on the treated plots than the untreated, but only marginally and usually not significantly so. Even the full programme of sulphur sprays in 2003 was unable to give good control of mildew on Pinova and only partial control on Topaz. The high levels of mildew caused russetting of the fruit, especially on the Pinova.

Leaf spot

Fungal spotting of leaves and occasionally fruits was present at low incidence in the orchard at Oakwood Farm in 2000-2003. In 2004 weather conditions favoured the disease which was present at high incidence on shoots particularly in replicate one,

where over 70 % of shoots were infected and some early defoliation had occurred although it was not possible to determine the contribution to the leaf fall made by the leaf spot infection compared to the apple scab that was also prevalent in this plot. Samples were sent to Global Plant Clinic at CABI Bioscience, Egham, Surrey for identification. Two fungal species were found to be present – *Botryosphaeria obtusa* (frog-eye leaf spot) and *Phoma ? rubefaciens*. The former also causes a fruit rot which was present on fruit at harvest.

Sooty blotch

There was a high incidence of sooty blotch on fruits at harvest in experiment 1 (Table 1a.8). The site was surrounded on three sides by mature mixed species hedges which are the inoculum source of the fungus and which with tree structure contribute to poor air circulation which favoured the disease. Studies on timing of colonisation of fruit by the sooty blotch fungus by sampling fruitlets from the orchard at two week intervals from early June in 2000, 2001 and 2003, followed by damp incubation in the laboratory for one month, indicated that fruit were first colonised in early July. Statistically significant differences between treatments were erratic and there was only limited evidence that the spray programmes applied to the experimental and grower's plots were reducing the incidence of sooty blotch. The incidence of sooty blotch was greatest in 2000 and 2002, which were wet years which also favoured scab. Over 40% of fruits had moderate or severe sooty blotch infection.

The incidence of sooty blotch infection was much lower in experiment 2, which had newly planted trees and much better air circulation (Table 1a.9). There was some limited evidence that the grower's spray programme was reducing the incidence but at best only marginally.

Apple blossom weevil

Apple blossom weevil, *Anthonomus pomorum*, was by far the most damaging pest in experiment 1 (Table 1a.10) but it did not occur in experiment 2 where the new orchard was planted in an area isolated from sources of infestation.

In the first year in experiment 1, no sprays were applied to control apple blossom weevil and approximately 30% of blossoms were capped by larvae at the end of blossom (Table 1a.10). Most of the damaged blossoms did not develop and many subsequently fell from the tree. At harvest, approximately 18% of fruits showed symptoms of damage by apple blossom weevil larvae. Damaged fruits were flattened, dense and had a distorted, cat-faced eye.

In subsequent years, the pyrethrum sprays applied to the experimental plots significantly reduced the amount of damage. Two sprays applied in 2002, 2003 and 2004 gave better control than the single sprays applied in 2001 or in the grower's plot in 2003 and 2004 which gave intermediate results. The rotenone (Derris) sprays applied to the grower's plots in 2002 had little effect.

The proportion of larvae parasitised by the parasitoid *Scambus pomorum* varied greatly from year to year with no obvious treatment differences until 2004, when much higher percentage parasitism occurred on the untreated controls than on the plots that had been sprayed with pyrethrum, providing limited evidence that the pyrethrum treatment may have been harmful.

Rosy apple aphid

Rosy apple aphid was only a significant problem in experiment 1 in the first year (2000) when approximately 14% of fruits by weigh and 20% of fruits by number were found at harvest to have rosy apple aphid damage (Table 1a.11). No treatments had been applied for the pest in that year so no treatment differences could be expected. In 2002, the percentage clusters infested pre-blossom was significantly smaller on the experimental and the grower's plots than the untreated, suggesting that the early sprays of pyrethrum or rotenone (Derris) for apple blossom weevil control, may have been having some partial controlling effect on rosy apple aphid, though only the experimental plots which had received the pyrethrum spray had a significantly lower incidence of damage at harvest.

The aphid was a much more significant problem on the young newly planted trees in experiment 2 (Table 1a.12). The distribution of damage was irregular with a high proportion of trees infested in some areas and no obvious treatment or variety effects in 2002. In 2003, the aphid was less prevalent. In 2004, the two early pyrethrum sprays had no significant effect on amounts of damage at harvest. Topaz was considerably more susceptible to infestation than Pinova.

Early caterpillar damage

At harvest, 2-10% of fruits had blemishes caused by early season feeding by winter moth and tortrix moth caterpillars on blossoms and young developing fruits (Table 1a.13). There were no statistically significant treatment effects and the early season *Bacillus thuringiensis* sprays were of no apparent benefit.

Codling and tortrix moths

Peak catches of codling moth in sex pheromone traps in experiment 1 exceeded the threshold of 5 moths per trap per week every year (Table 1a.14). However, particularly large numbers were captured in 2000 and 2002. Peak catches of fruit tree tortrix moth (*Archips podana*) were at or above the threshold of 30 moths per trap per week every year, with high numbers also in 2000 and 2002. Peak summer fruit tortrix moth (*Adoxophyes orana*) were below the threshold of 30 moths per trap per week every year.

Despite this, the incidence of codling moth damage to fruits at harvest was very low in every year except the final year, 2004, on all plots (Table 1a.15). The application of codling moth granulovirus sprays applied in the first 3 years to the experimental plots was abandoned because little damage was occurring on the untreated or the grower plots that received no treatment. In the final year, approximately 8% of fruits were damaged on all plots, despite the low peak catch of moths in the pheromone trap. The reason for this is unclear. There was a low incidence of damage to fruit due to tortrix moth caterpillars at harvest with no obvious treatment effects.

Tree nutrition

Mineral analysis each year showed that N levels in leaves in both experiment 1 and experiment 2 were usually below the target levels of 2.5 % N dry weight (Tables 1.16 and 1.17). In experiment 1, composted fertiliser (Laws, Wisbech, High N fertiliser analysis 6:3:3) was applied at a rate of 1.7 tonnes (=200 kg N) per ha in spring each year, starting in 2001. The N concentrations in leaves did gradually increase from the very low levels of 1.6% in 2000 to 2.1% in 2004, but they were still below the threshold of 2.5% which is regarded as the minimum acceptable level in conventional orchards. In 2000, the foliage of the orchard did have a general yellowish, N deficient appearance, but the colour has improved by 2004. A similar improvement was seen in experiment 2, presumably as a response to the foliar N sprays applied and greater root penetration of the soil as the trees established. Concentrations of N in fruit samples showed similar trends in experiment 1, averaging 36 mg/100 g and well below the threshold of 50 mg/100 g in 2000 but increasing to 51 mg/100 g by 2004.. However, N levels in fruits in experiment 2 were consistently low, especially on Topaz.

Yield and quality

Experiment 1: There were large, statistically significant (P=0.05) differences between treatments in yield and quality (Table 1a.18). Yield varied considerably from year to year, with the greatest variation (95 fold) in the untreated controls and the smallest variation (2.6 fold) for the experimental treatment and with the grower's treatment having intermediate degree of variation (17 fold).

The experimental treatment consistently had the greatest yield averaging 17.4 tonnes/ha. The average yield in the grower's treatment was 11.6 tonnes/ha. This treatment generally had intermediate yields except in 2004 when grazing damage to the lower branches by deer particularly reduced yield in two of the growers plots. The untreated control had the lowest yield (mean = 8.7 tonnes/ha), except in 2004 due to deer damage to the growers plots. Thus the experimental treatment on average produced a 50% greater yield than the grower's treatment which in turn yielded 33 % more than the untreated control on average.

Counts of the numbers of fruits harvested and measurements of fruit diameter showed that most of the differences in yield were caused by differences in the numbers of fruits harvested, fruit size being generally very similar for all treatments.

The experimental treatment generally had the highest percentage of fruits in the class I quality grade, though there was very considerable year to year variation and differences were only statistically significant in 3 out of the 5 years.

Experiment 2: Yields were very small and variable because the orchard was only just establishing (Table 1a.19). The data was not subjected to statistical analysis. No meaningful conclusions about the effects of treatments on yield could be drawn.

Economic results

Experiment 1: As in conventional systems, marketable yield (grade out) and prices received for fruit were some of the key determinants of the economics of various treatments. Although higher prices, with premiums for organic fruit commonly of 100% over conventional ones, mean that overall economic returns can be obtained with lower yield levels.

Financial output (yield x price) tended to mirror the varying levels of yield from the different treatments. On average financial output from the experimental treatments were 1.71 times higher than the growers and 2.2 times higher than the untreated ones. It is also notable that although all the financial returns were variable, from year to year, they were less variable on the experimental treatments and always positive. Since, many of the costs of production and marketing (approximately 50%) are also related to the level of yield (picking, storage, grading, packing and marketing) then the yield differences were also quite directly reflected in net margins. On average the net margins from the experimental treatments (£6,038/ha or 35p/kg) was 2.32 times higher than the growers (£2,602/ha or 21p/kg) and 4.5 times higher than the untreated (£1303/ha or 14/kg). The average cost of the sprays (detailed in Table 1a.1) on the experimental treatments at £400/ha accounted for only 4% (2p/kg) of total costs of production and were £237 (2% (0.6p/kg) higher than the grower treatment costs. The costs of sprays were therefore small and could easily be justified in terms of achieving a 2.32 times increase in net margin.

Experiment 2: Since the orchard was replanted in 2002, during the course of the project monitoring there was insufficient yields from the orchard to warrant a full economic analysis.

Apart from establishment costs, the only costs incurred in this young orchard were for sprays (in treated plots) and weed control. Sprays were used to boost nutrition, and control pests and diseases with material costs at £ 77/ha in 2003 and £681/ha in 2004. In 2004 the costs were higher than site 1 as more of the product Py Insect Killer (pythreum) was used. Weed control was an important issue in the young orchard. The owner purchased a flame burner and this was used to control weeds and grasses in a strip either side of the tree. The costs were estimated at £124/ha per pass. In 2003 it was used for 6 passes during the growing season then the cost is estimated at £745/ha.

DISCUSSION (OBJECTIVE 1a, FINAL REPORT)

Scab

In experiment 1 where the scab susceptible variety Fiesta was used, in seasons favourable to scab (2002, 2004), the fungicide programme applied to the experimental plots, based on early copper sprays followed by sulphur gave only partial control of scab. The early copper sprays however, did limit scab development on fruit and ensure a crop, Sulphur applied pre and post bloom failed to control scab, so that a high incidence of scab developed on extension growth post bloom ensuring a high incidence of overwintering scab and a high potential scab risk for the following season, without effective means of eliminating overwintering leaf litter. In experiment 2 a similar result was obtained with the scab susceptible variety Pinova, whereas the incidence of scab on the scab resistant (Vf resistance) variety Topaz remained zero or low even in untreated plots in the high risk scab seasons 2002 and 2004. This shows that scab resistant varieties are a key requirement for successful organic production in scab prone areas. There is still however a need to apply an integrated control programme for scab to these varieties, making use of early copper sprays and methods to encourage leaf rotting in the autumn in order to preserve the scab resistance.

Mildew

In experiment 1 where the location at Oakwood Farm was relatively low risk for mildew, even for the mildew susceptible variety Fiesta, use of sulphur sprays post blossom, combined with removal of primary mildew in spring to minimise inoculum, provided adequate control of powdery mildew. The dose of sulphur used post blossom could be adjusted depending on the mildew risk identified based on disease monitoring and forecasts of mildew risk using ADEM (Berrie & Xu, 2003). However in experiment 2, located in East Kent where local conditions are generally much more favourable for mildew, intensive programmes of sulphur would be required to maintain control on susceptible varieties such as Pinova or Topaz. With the need to minimise overwintering inoculum, there would probably be few opportunities to adjust the sulphur dose according to risk.

Sooty blotch

The results clearly show that sooty blotch can be a damaging disease in organic apple production, especially in orchards with poor air circulation and mature mixed species hedgerows (e.g. in experiment 1). Washing or scrubbing the fruit may slightly reduce disease symptoms but are inadequate when the disease is severe or well established. The disease will also continue to develop in cold store. In these experiments, sooty blotch was ignored in the assessment of class I and class II quality grades. In reality, if this disease had been included in the quality assessment very little fruit would have been of class I quality in experiment I, particularly in 2000 and 2002 when sooty blotch incidence was high. There was evidence that the copper and sulphur spray programmes applied were of some benefit in reducing sooty blotch. At best, the spray programmes gave a limited reduction in disease incidence/severity. Control of sooty blotch is vital for organic production. Sooty blotch is caused by the fungus *Gloeodes pomigena*, however recent studies in the USA have shown that sooty blotch disease is caused by a complex of at least 3 fungi, rather than *G pomigena*, the composition of which is dependent on region, orchard and treatment. The presence of a fungus complex may influence the success of control treatments applied Clearly, a better understanding of the biology and epidemiology of sooty blotch disease in the UK is required if better methods of controlling this disease are to be devised Six et al (1997) found that sprays of Steinhauers Mehltauschreck (SMS) or of coco soap gave control of sooty blotch. Disease models have been developed in the USA as an aid to spray timing and Trapman (2001) has developed a simulation programme for sooty blotch infection and found that sprays of lime sulphur or coconut soap aimed at severe infection periods as indicated by the model provided 72-100% control. However, in a separate small plot spray trial conducted as part of this project, application of multiple sprays of copper oxychloride, sulphur, kaolin or extract of coconut+citrus+calcium carbonate (Crop Life) had no effect in reducing sooty blotch infection. Although in this trial it is likely that the first sprays were applied late and after sooty blotch colonisation of the fruit had started. Cultural control measures will provide a partial solution to this disease problem, further investigation of its biology and epidemiology, construction and evaluation of infection period simulation models and evaluation of alternative organically acceptable fungicide and biocontrol agents is required to develop solutions for this important problem in organic apple production.

Apple blossom weevil

Apple blossom weevil was by far the most damaging pest in this project causing large losses in yield and quality on cv Fiesta in experiment 1. It did not occur in experiment 2 because there was no source of infestation nearby and the pest had not invaded in the first 3 years of orchard establishment. Unlike many other apple varieties, Fiesta suffers substantial quality injury from blossom weevil attack. This is because a significant proportion of capped blossom do not abciss and fall from the tree but continue to develop to harvest. However, such fruits are distorted and would usually be only suitable for juice. Apple blossom weevil was a severe pest in conventional apple production before the advent of modern insecticides. This work shows that application of early season sprays of pyrethrum targeted against adults as soon as they emerge in spring and before substantial oviposition has occurred is a fairly effective way of controlling the pest. The work indicates that 2 sprays are better than one and that Derris is ineffective. Unfortunately, the results indicate that the pyrethrum sprays may be harmful to the parasitoid *Scambus pomorum*, an important natural enemy of apple blossom weevil. The results indicate that the percentage parasitism varies greatly from year to year and the parasite cannot naturally regulate pest numbers sufficiently to prevent substantial economic damage. Labanowska (2002) and Svensson (2002) have recently found that sprays of natural pyrethrum (40 g a.i./ha) can control strawberry blossom weevil, *Anthonomus rubi*. Pyrethrum is a broad spectrum insecticide which is harmful to many natural enemies and is extremely toxic to fish and other aquatic life. Use is not sustainable and does not fit well with the ethos organic production. Alternatives need to be found for control of this damaging pest in organic apple production, the most promising being identification and exploitation of the weevil's aggregation pheromone, a task which has been partially completed in a separate research project by East Malling Research and the Natural Resources Institute.

Rosy apple aphid

In experiment 1, rosy apple aphid was a significant problem in the first year but thereafter only occurred at low levels, even in 2004 which was generally a year of exceptionally high incidence of the pest in SE England as there was an unusually large migration of the aphid to apple in autumn 2003. Wyss (1999) and Kienzle and Zebitz (1997) found that predatory spiders (mainly *Araniella* spp.) are more abundant in organic systems where ground herbage is present under the trees and that they significantly decrease aphid populations. Insect predators and ladybird larvae parasitoids have been found to reduce numbers of aphids in organic systems (e.g. Wyss, 1997; Wyss et al, 1999). One possible explanation for the low incidence of rosy apple aphid in experiment 1 is that aphid numbers were reduced, perhaps both in the autumn and spring, by natural enemies. Another possible explanation is that is the low nitrogen status of the trees made them less attractive or suitable for migrants in the autumn.

Rosy apple aphid was a more serious problem on the young establishing trees in experiment 2. The variety Topaz was particularly susceptible and the small number of attacked trees scattered erratically among uninfested ones, were very badly damaged. These results suggest that rosy apple aphid control is especially important in newly planted orchards. The early season sprays of pyrethrum, applied to control adults of apple blossom weevil adults in experiment 1, gave partial control of rosy apple aphid

but are likely to be inadequate in establishing orchards. Other work in this project has shown that spays of pyrethrum in the autumn can give a useful level of control. In other EU countries neem extract is known to be effective for control of rosy apple aphid in organic systems (Kienzle et al, 1997; Wyss, 1997) but regrettably this insecticide in not registered in the UK currently.

Early season caterpillar damage

Early season sprays of *Bacillus thuringiensis* (Bt) did not prevent a low but significant level of early season caterpillar injury to fruits. Poor results in controlling larvae early in the spring have been reported by several authors (reviewed by Cross et al, 1999). The Bt toxin has to be ingested to act and feeding rates can be low when temperatures are low. Furthermore, the cryptic feeding habits of winter moth and tortrix moth larvae mean that the plant tissue on which larvae are feeding is less exposed to spray deposits. It is possible that improved control could be achieved by application of multiple sprays but this would be costly.

Codling and tortrix moths

Although codling moth is a key pest of apples that is known to cause serious economic damage at low population densities, interestingly, it was not a significant problem in the first 4 years of experiment 1, despite high, above threshold pheromone trap catches in all years, and especially in the early years. Sprays of codling moth granulovirus applied for the experimental treatment were unnecessary and were abandoned, though this decision was found to be incorrect in the final year. One possible explanation is poor oviposition or poor survival of eggs either due to unfavourable weather conditions (wet or cold weather) or predation in 2000-2003. However, the need for codling moth treatment in organic systems was demonstrated in 2004 when significant damage (8%) was caused mainly by the second generation in August-September. Organically acceptable treatments for these pests include application of granuloviruses or sex pheromone mating disruption, both of which have been applied extensively and successfully in organic apple production (e.g. Simon et al, 1999; Villa Gil, 1998;. Weibel et al, 2004).

Tree nutrition

Apple trees grown on dwarfing rootstocks are very sensitive to competition from ground herbage for moisture and nutrients. In organic apple production it is difficult to maintain bare soil in the tree rows and to provide adequate N, at least when production is on a large scale. In both experiments 1 and 2 the entire soil surface was grass, mown several times per year in experiment 1 but mown occasionally in the alleys only in experiment 2. The leaf and fruit mineral analyses showed that the trees were deficient in N throughout the duration of the experiments, though the annual application of organic fertiliser did appear to improve N levels in experiment 1. The low N levels probably contributed substantially to the low yield performance in experiment 1 and the slow establishment in experiment 2. Low N levels probably also made the trees more prone to losses due to apple blossom weevil in experiment 1 because of low fruit bud numbers would have been less able to compensate for bud losses due to attack by the pest, though it may have been beneficial in making the trees less susceptible to other pest such as aphids. Although investigation of the

effects of tree nutrition was not the subject of this project it is clear from the results that nutrition, in particular removal of competition from ground herbage and adequate provision of N, are important for successful for organic apple production.

Yield and quality

The results of experiment 1 in particular demonstrated substantial yield and significant quality benefits from the experimental IPDM programme. The fact that the yield increases were due almost entirely to increases in fruit number rather than fruit size indicate that the IPDM programme was preventing losses of buds, flowers and fruits due to pest and disease attack and possibly enabling slightly stronger growth of trees and consequently higher fruit bud numbers to develop, though counts of fruit bud numbers were not made. The pest and disease assessments and the incidence of damage at harvest indicate that the losses were caused principally by scab and apple blossom weevil. The improved spray programmes for these made substantial differences to yield. The results imply that severe scab infections in 2000 and 2002 caused fruits to abciss from the tree either directly by direct infection or by weakening the vegetative growth.

CONCLUSIONS (OBJECTIVE 1a, FINAL REPORT)

Scab

- The results demonstrate the crucial importance of scab resistant varieties for organic apple production. Spray programmes of copper and sulphur did not prevent damaging scab infection on susceptible varieties in high risk scab years, even though they gave reasonable control in low risk years.
- Converting established conventional orchards of disease susceptible varieties (Cox, Gala, Bramley, Fiesta etc) to organic production is not likely to be successful.
- A better approach is to plant new orchards of disease resistant varieties. Scab resistance is vital and mildew resistance is vital in mildew prone areas. (Pinova is too susceptible to both scab and mildew for organic production)
- Destruction of overwintering sources of scab on leaf litter (e.g. by maceration) is important
- Three early season sprays of copper (1 pre-bud burst, 2 at bud burst and mouse ear) gave fairly good early season control of scab on fruit and rosette leaves, ensuring a crop but may not prevent a severe subsequent build up of leaf infection on extension growth during summer.
- Sulphur had at best only limited activity against scab.

Mildew

- Minimising primary mildew incidence by removal during winter pruning and in spring (primary blossom mildew and primary vegetative mildew) will improve growing season control of mildew and is an essential part of the integrated approach

- Highly mildew susceptible varieties like Pinova should be avoided for organic production in mildew prone areas because they will require intensive sulphur spray programmes to control mildew effectively.
- A programme of sprays of sulphur at 50-100% of the dose is moderately effective for mildew control but the programme has to be maintained throughout the period of extension growth (April-August). Higher volume sprays at the full dose are necessary in mildew prone areas on susceptible varieties.

Leaf spot

- Leaf spots caused by *Phoma* sp or *Botryosphaeria obtusa* although normally present at low incidence and causing little damage, under favourable warm wet weather can spread rapidly, causing premature leaf fall and some spotting to fruit.
- Early season copper sprays appeared to give very little control of the problem.
- Additional work may be needed to understand the epidemiology and significance of these diseases.

Sooty blotch

- Sooty blotch colonisation of fruits is likely to be a serious problem in organic orchards with poor air circulation which favour the disease.
- Spray programmes of copper and sulphur had at best only limited effects.
- A better understanding of the epidemiology of this fungus is essential if alternative means of controlling this disease in organic production are to be identified.

Apple blossom weevil

- Apple blossom weevil was the most important pest causing large losses in yield and quality in the established orchard where it occurred. It did not occur in the newly planted orchard which was isolated from sources of infestation during the first three years of establishment.
- Parasitism by the parasitic wasp *Scambus pomorum* varied greatly from year to year and did not naturally regulate apple blossom weevil numbers sufficiently to prevent significant crop damage by the pest.
- Two early season sprays of pyrethrum (Py Insect Killer) targeted against adults around bud-burst were shown to give fairly good (~80%), though not complete, control of apple blossom weevil. A single spray was less effective and sprays of rotenone (Derris) were ineffective.
- Use of sprays of pyrethrum to control apple blossom weevil does not fit well with the aims of organic production and alternative control strategies, based on the use of the weevils aggregation pheromone, need to be developed

Rosy apple aphid

- Rosy apple aphid caused significant damage to the young trees in the newly planted orchard

- It was much less of a problem in the established orchard, even in spring 2004, when the pest was at very high levels in conventional orchards throughout SE England
- Topaz was considerably more susceptible to infestation than Pinova.
- Early season pyrethrum sprays (for apple blossom weevil) gave some reduction in infestation.

Codling moth

- Although codling moth is a key pest of apples that is known to cause serious economic damage at low population densities, it was not a significant problem in the first 4 years of experiment 1, despite high, above threshold pheromone trap catches.
- However, the need for codling moth treatment in organic systems was demonstrated in 2004 when significant damage (8%) was caused mainly by the second generation in August-September. Sprays of codling moth granulovirus provide an organically acceptable control method for codling moth.

Early season caterpillar damage

- There was a moderate incidence (<10% fruits at harvest) of early season caterpillar feeding on blossoms and young developing fruits which resulted in blemishes on fruits at harvest. Early season *Bacillus thuringiensis* sprays did not greatly reduce the incidence of this damage.

Tree nutrition

- N levels in leaves and fruits in the organic orchards were usually below the target levels considered optimal for conventional production and the foliage had a general yellowish, N deficient appearance.
- Application of organic high N fertiliser analysis appeared to improve levels in one experiment, but not to the optimal level.
- Low N levels are likely to have significant adverse affects on tree growth, bud strength and fruit set and are likely to be a cause of erratic and low average yields in organic apple production.
- For successful organic apple production, means of overcoming competition from ground herbage for moisture and nutrients and of provision of N are likely to be of vital importance to successful organic production.

Yield and quality

- The experimental treatment on average produced a 50% greater yield than the grower's treatment which in turn yielded 33 % more than the untreated control on average.
- Differences in yield were caused by differences in the numbers of fruits harvested.
- The experimental treatment generally had the highest percentage of fruits in the class I quality grade.

Economic results

- Financial returns (net margins) from the experimental treatments were consistently higher than both the grower and untreated ones.
- Financial returns from the experimental treatments were less variable than both grower and untreated ones and always positive.
- The costs of the sprays (or perhaps IPDM programme?) used on the experimental treatments, at 4% (2p/kg) of total costs of growing and marketing, were relatively small and easily justified in terms of the increased financial returns (2.3 fold) relative to the growers.

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Table 1a.1. Summary of foliar sprays fungicide and insecticide sprays applied to the experimental and growers plots in each of the five years of the IPDM experiment in the converted organic apple (cv. Fiesta) orchard at Oakwood farm

Foliar sprays applied	Experimental treatment					Growers treatment				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Disease control										
Copper bud-burst	0	1	1	1	1	0	0	0	1	1
No of additional copper sprays pre-blossom	0	0	0	1	2	0	0	0	0	0
No. of leaf fall copper sprays	0	0	1	0	0	0	0	1	0	0
No. sulphur sprays	15	9	7	2	7	15	9	6	0	0
Rate of sulphur application (kg a.i. / ha)	3.6[1]	9.0	9.0	4.0	9.0	3.6[1]	3.6[1]	4.8	-	-
Pest control										
No. of early pyrethrum sprays	0	1	2	2	2	0	0	0	1	1
No. of early Derris sprays	0	0	0	0	0	0	0	2	0	0
No. of BT sprays	4	3	0	1	1	2	1	0	0	0
No. Carpovirusine sprays	4	2	2	0	0	0	0	0	0	0
No. compost tea applications	0	0	0	0	0	0	0	4	8	3
Spray volume (l/ha)	125	1000	1000	1000	1000	125	125	375	1000	1000

[1]Except first spray at 7.2 kg/ha

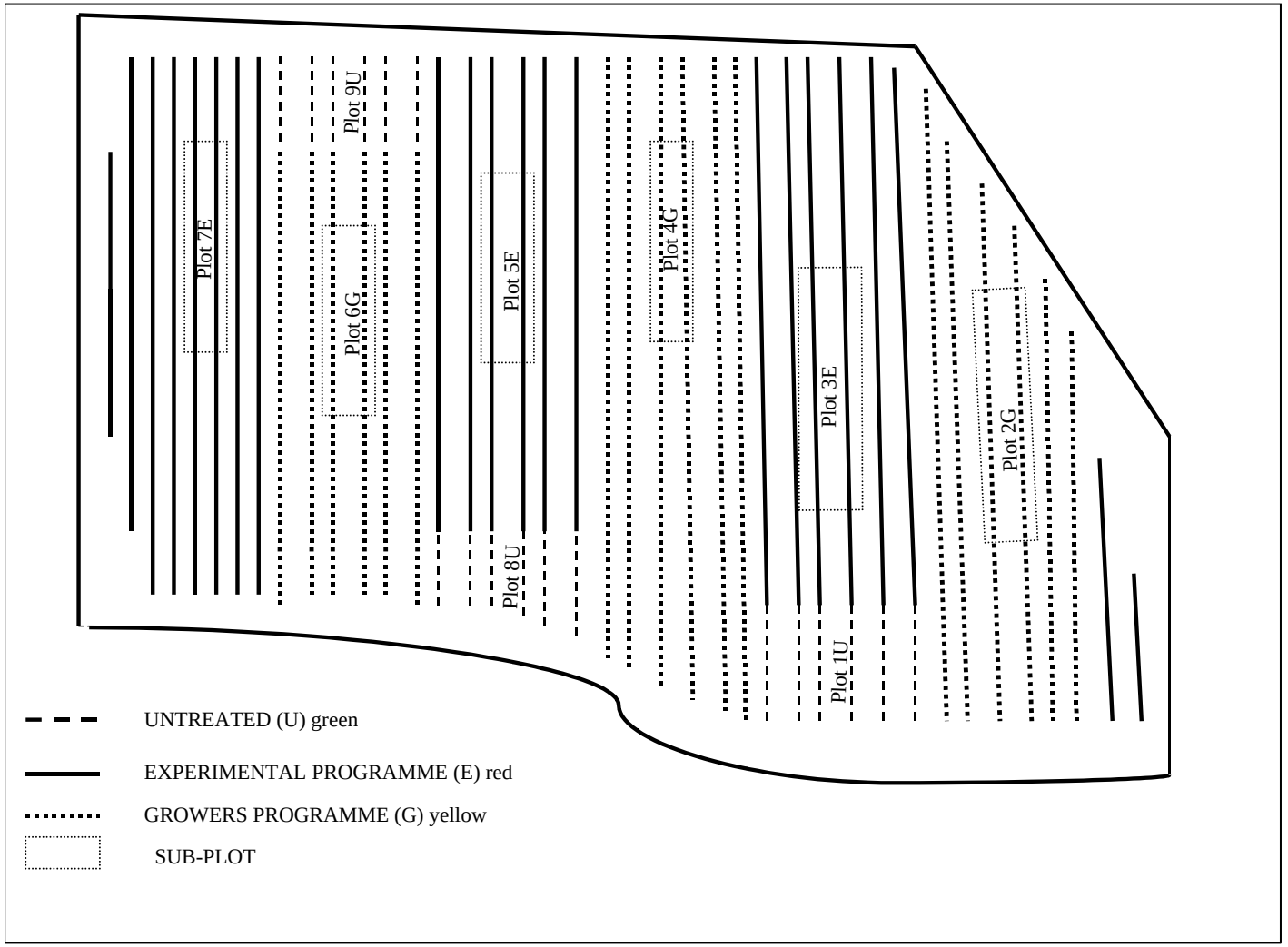

Figure 1a.1. Experimental layout in the IPM trial at Oakwood farm in 2003. Note the untreated control plots have been relocated.

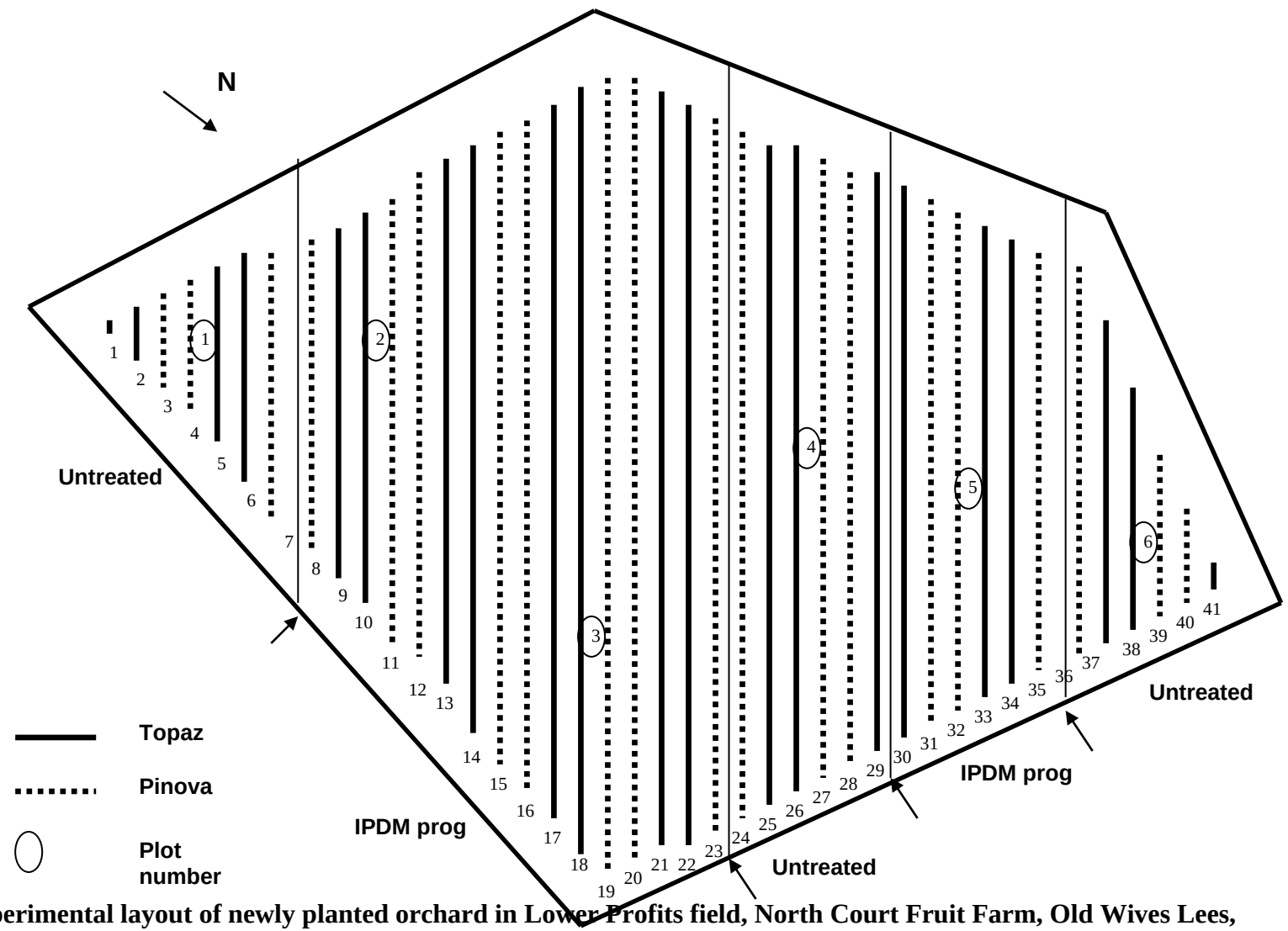

Figure 1a.2. Experimental layout of newly planted orchard in Lower Profits field, North Court Fruit Farm, Old Wives Lees, Canterbury, Kent

Table 1a.2. Summary of foliar sprays fungicide and insecticide sprays applied to the experimental and growers plots in each of the three years of the IPDM experiment in the newly planted organic apple orchard at North Court Farm

Foliar sprays applied	2002	2003	2004
Disease control			
Copper bud-burst	1	1	1
No of additional copper sprays pre-blossom	0	0	2
No. of leaf fall copper sprays	0	0	0
No. sulphur sprays	3	2	9
Rate of sulphur application (kg a.i. / ha)	8.0	3.2	4.0-8.0†
Pest control			
No. of early pyrethrum sprays	0	0	2
No. of BT sprays	0	0	1
Foliar nutrient sprays applied	4	3	9
Spray volume (l/ha)	1000	1000	1000

†First 3 sprays applied at 8.0 kg a.i./ha, the rest at 4.0 kg a.i./ha

Table 1a.3. Mean number of scab infection periods predicted by ADEM at East Malling

	2000	2001	2002	2003	
March	2	7	5	0	
April	14	5	1	3	
May	11	3	9	4	
June	4	5	7	8	
July	9	1	8	10	

Table 1a.4. Mean† incidence of scab infection in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% trees infected pre-blossom		
2000	100	100	100
2001	0	0	3.3
2002	30a	97b	100b
2003	0	0	0
2004	0	0	0
	% trusses infected at end of blossom- early fruitlet		
2000	93	95	97
2001	2a	16b	6b
2002	43a	92b	96b
2003	13a	30b	28b
2004	24a	80b	81b
	% shoots infected in June-July		
2000	56a	66ab	88b
2001	1a	28b	26b
2002	95	99	100
2003	35a	71b	65b
2004	94	100	99
	% by weight fruits infected at harvest		
2000	58a	54a	81b
2001	1a	8a	8a
2002	71a	93b	91b
2003	7a	36b	24b
2004	36a	88b	90b
	% by no. fruits infected at harvest		
2000	59a	77ab	83b
2001	1a	8a	8a
2002	71a	93b	92b
2003	7a	36b	24b
2004	25a	93b	90b

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.5. Mean† incidence of scab infection in the experimental and untreated plots in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Farm

Year	Experimental treatment		Untreated	
	Topaz	Pinova	Topaz	Pinova
% trees infected pre-blossom				
2002	0	27	0	48
2003	0	0	0	0
2004	0	35	0	100
% shoots infected in June-July				
2002	0	73	0	84
2003	0	28	0	32
2004	1	13	2	75
% (by no.) fruits infected at harvest				
2002	0	63	0	77
2003	0	2	0	5
2004	0	19.8	0	34.5

Table 1a.6. Mean† incidence of mildew infection in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% blossom trusses with 1º mildew		
2000	0.3	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0.1
2004	0	0	0
	% shoots infected 2° mildew in June-early July		
2000	12a	24a	56b
2001	2a	6a	17b
2002	5a	10a	46b
2003	27a	66b	68b
2004	58a	100b	93b
	% shoots infected in late July - August		
2000	11a	8a	34b
2001	1a	5a	25b
2002	11a	15a	32b
2003	38a	85b	78b
2004	47a	96b	75b

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.7. Mean† incidence of mildew infection in the experimental and untreated plots in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Fruit farm

Year	**Experimental treatment**		**Untreated**	
	Topaz	**Pinova**	**Topaz**	**Pinova**
No. blossom trusses with 1º mildew/20 trees				
2002	0	1	2.3	0
2003	1.4a	3.4a	13.2b	5.4a
2004	78a	120b	162b	218c
% shoots infected 2° mildew in June-early July				
2002	43a	67a	53a	59a
2003	15a	51b	21a	68b
2004	12a	43b	54b	98b
% shoots infected in late July - August				
2002	-	-	-	-
2003	55a	77b	75b	98b
2004	52a	99b	83b	100b
% fruits with severe russet at harvest				
2002	-	-	-	-
2003	12a	11a	8a	27b
2004	11a	45b	13a	47b

Table 1a.8. Mean† % fruits with different severities of sooty blotch infection in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% fruits with no sooty blotch at harvest		
2000	19a	20a	13a
2001	71a	41c	53b
2002	9a	2a	10a
2003	67a	46b	66a
2004	76	58	58
	% fruits with slight sooty blotch at harvest		
2000	40b	28a	27a
2001	24a	30a	25a
2002	35a	7a	38a
2003	28a	37b	25a
2004	21	22	30
	% fruits with moderate sooty blotch at harvest		
2000	23a	34a	24a
2001	5a	19c	16b
2002	41a	42a	41a
2003	5a	14a	8a
2004	3	18	10
	% fruits with severe sooty blotch at harvest		
2000	18a	18a	36b
2001	1a	10b	6b
2002	15a	27a	11a
2003	1a	4a	1a
2004	1	2	3

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.9. Mean† % fruits with different severities of sooty blotch infection in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Fruit farm

Year	Experimental treatment		Untreated	
	Topaz	Pinova	Topaz	Pinova
% fruits with no sooty blotch at harvest				
2002	68	76	46	58
2003	99	98	99	96
2004	87	60	67	40
% fruits with slight sooty blotch at harvest				
2002	27	20	42	33
2003	1	2	1	4
2004	11	32	13	31
% fruits with moderate sooty blotch at harvest				
2002	4	3	8	8
2003	0	0	0	0
2004	3	8	9	19
% fruits with severe sooty blotch at harvest				
2002	1	0	4	1
2003	0	0	0	0
2004	0	0	11	25

Table 1a.10. Mean† incidence and damage by apple blossom weevil in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% blossoms capped by apple blossom weevil larvae		
2000	26a	29a	35a
2001	19a	40b	37b
2002	15a	43b	52b
2003	5a	12b	11b
2004	4a	10ab	20b
	% larvae parasitised		
2000	14	18	20
2001	4	5	1
2002	32	32	32
2003	-	-	-
2004	2	3	20
	% by weight fruits damaged at harvest		
2000	13a	18a	21a
2001	29a	40ab	53b
2002	8a	25b	16b
2003	6a	11ab	14b
2004	12a	40b	36b
	% by no. fruits damaged at harvest		
2000	13a	18a	21a
2001	31a	42ab	55b
2002	9a	26b	19b
2003	6a	12ab	16b
2004	14a	42b	42b

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.11. Mean† incidence and damage by rosy apple aphid in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% clusters infested with rosy apple aphid pre-blossom		
2000	1.7	2.3	1.5
2001	0.7	6.3	5.7
2002	18.3a	16.7a	35.0b
2003	0	0.2	0.3
2004	0	0.2	0.5
	% fruits by weight damaged by rosy apple aphid at harvest		
2000	15.9a	11.4a	14.1a
2001	1.2	0.6	1.1
2002	6.3a	15.1b	17.2b
2003	0	0.2	0.6
2004	0.3	0.7	1.4
	% fruits by no. damaged by rosy apple aphid at harvest		
2000	21.4a	16.4a	20.8a
2001	2.1	0.8	1.6
2002	9.3a	17.2b	16.1b
2003	0	0.2	0.7
2004	0.3	0.7	1.4

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.12. Mean† incidence and damage by rosy apple aphid in the experimental and untreated plots in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Fruit Farm

Year	Experimental treatment		Untreated	
	Topaz	Pinova	Topaz	Pinova
Trees out of 20 infested with rosy apple aphid pre-blossom				
2002	8	25	18	8
2003	5	0	0	6
2004	2	1	9	0
% fruits with rosy apple aphid at harvest				
2002	27	37	17	15
2003	9	3	5	0
2004	28	12	35	12

Table 1a.13. Mean† incidence and damage by winter and tortrix moth caterpillars in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	% trusses with winter moth at green cluster		
2000	1	3	3
2001	1	3	3
2002	0	1	1
2003	0	1	1
2004	0	1	2
	% by weight fruits with early caterpillar feeding scars at harvest		
2000	8a	5a	9a
2001	2a	3a	2a
2002	7a	10a	7a
2003	4a	3a	6a
2004	6a	4a	5a
	% by no. fruits with early caterpillar feeding scars at harvest		
2000	8a	5a	9a
2001	2a	3a	2a
2002	7a	10a	8a
2003	4a	3a	5a
2004	6a	4a	5a

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.14. Peak weekly catch of codling and tortrix moth adults in sex pheromone traps in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Codling moth	Fruit tree tortrix moth	Summer fruit tortrix moth
2000	70	119	23
2001	11	88	21
2002	66	135	27
2003	21	30	18
2004	14	30	14

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.15. Mean† incidence and damage by codling moth and tortrix moth caterpillars in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
% trusses with tortrix moth at green cluster			
2000	4	3	4
2001	5	10	5
2002	4	7	12
2003	4	4	7
2004	5	9	9
% by weight fruits damaged by tortrix moth at harvest			
2000	6	6	5
2001	6	6	5
2002	3	4	3
2003	1	4	3
2004	3	3	5
% by no. fruits damaged by tortrix moth at harvest			
2000	6	6	5
2001	6	6	5
2002	3	5	3
2003	1	3	3
2004	3	3	5
% by weight fruits damaged by codling moth at harvest			
2000	1.5	0.6	0
2001	0.3	0.4	0.4
2002	1.0	1.0	0
2003	1.1	1.3	2.4
2004	8.0	8.4	7.7
% by no. fruits damaged by codling moth at harvest			
2000	1.5	0.5	0
2001	0.3	0.4	0.5
2002	0.9	1.0	0
2003	1.1	1.3	2.4
2004	8.0	8.4	7.7

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.16. Mean concentrations of N in leaf samples in Summer and in fruits at harvest in experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
Mean concentration N in leaf samples (% dry weight)			
2000	1.61	1.68	1.50
2001	1.47	1.49	1.48
2002	1.95	2.03	2.10
2003	1.73	1.80	2.00
2004	2.13	2.12	1.94
Mean concentration N in fruit samples (mg per 100 g))			
2000	33.5	35.7	38.4
2001	22.3	22.1	23.6
2002	41.2	55.9	45.6
2003	39.0	39.0	39.0
2004	48.0	52.0	52.0

Table 1a.17. Mean concentrations of N in leaf samples in Summer and in fruits at harvest in experimental and growers plots in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Fruit Farm

Year	Experimental treatment		Untreated	
	Topaz	Pinova	Topaz	Pinova
Mean concentration N in leaf samples (% dry weight)				
2002	1.80	1.94	1.80	1.94
2003	1.70	2.02	1.70	2.02
2004	2.31	2.51	2.43	2.58
Mean concentration N in fruit samples (mg per 100 g))				
2002	27.9	33.5	27.9	33.5
2003	35	51	35	51
2004	22	30	27	38

Table 1a.18. Mean yields, mean numbers of fruits per tree, mean diameter and % (by weight) fruits in the class I and class II quality grades in the experimental and growers plots in each of the five years of the IPDM experiment at Oakwood farm

Year	Experimental treatment	Growers treatment	Untreated
	Mean total yield (tonnes/ha)		
2000	13.6a	10.6a	3.8b
2001	17.5a	13.2a	9.0a
2002	10.1b	1.5a	0.2a
2003	26.3a	25.8a	18.9b
2004	19.6a	6.8b	11.7ab
	Mean no. fruits per tree		
2000	144a	102a	40b
2001	159a	139a	91a
2002	118b	19a	5a
2003	272a	272a	178b
2004	174a	60b	120ab
	Mean fruit diameter		
2000	-	-	-
2001	67.2	68.7	68.0
2002	64.5	63.2	62.5
2003	72.6	71.9	71.9
2004	70.2	70.2	66.7
	% fruits in class I		
2000	24a	30a	19b
2001	59a	35b	32b
2002	20a	3a	16a
2003	42a	33b	30b
2004	73a	47b	41b
	% fruits in class II		
2000	53a	53a	46a
2001	28a	26a	39a
2002	41a	36a	32a
2003	41a	41a	48b
2004	23a	34b	33b

† values in any row followed by the same letter do not differ significantly (P = 0.05)

Table 1a.19. Mean yields, mean numbers of fruits per tree, mean diameter and % (by weight) fruits in the class I and class II quality grades in the experimental and growers plots in each of the three years of the IPDM experiment in the newly planted organic orchard at North Court Fruit Farm

Year	Experimental treatment		Untreated	
	Topaz	Pinova	Topaz	Pinova
Mean total yield (tonnes/ha)				
2002	-	-	-	-
2003	1.02	1.31	0.76	0.74
2004	2.04	2.04	1.93	1.59
Mean no. fruits per tree				
2002	-	-	-	-
2003	7.5	11.4	6.3	6.5
2004	11.4	13.8	11.1	11.4
Mean fruit diameter				
2004	72.6	62.9	71.8	52.0
% fruits in class I				
2004	68	47	51	28
% fruits in class II				
2004	27	36	33	44

Table 1a.20: Average economic results 2000-2004 in experiment 1

	2000	2001	2002	2003	2004	Average
Untreated						
Total yield	3.8	9.0	0.2	18.9	11.7	9
Mkt. Yield (t)	2.47	6.39	0.1	14.67	8.74	6
Mkt yield (%)	65	71	48	77.6	75	68
Juice (%)	31	29	52	22	25	7
Output (£/ha)	3,150	8,066	115	17,600	10488	7,764
Cost of sprays (£/ha)	0	0	0	0	0	0
Other costs (£/ha)†	4,906	6,803	3,744	10,702	7,901	6,811
Net margin (£/ha)	-1,767	1,256	-3,609	7,737	3,031	1,330
Growers						
Total yield	10.6	13.2	1.5	25.8	6.8	12
Mkt. Yield (t)	8.8	8.05	0.58	18.9	5.49	8
Mkt yield (%)	83	61	39	73.3	81	67
Juice (%)	16	39	61	27	19	7
Output (£/ha)	10,771	10,419	831	23,727	6,789	10276
Cost of sprays (£/ha)	187	73	159	298	96	163
Other costs (£/ha)†	7,841	7,753	4,025	12,834	6,294	7,749
Net margin (£/ha)	2,778	2,606	-3,350	10,583	394	2,602
Experimental						
Total yield	13.6	17.5	10.1	26.3	19.6	17
Mkt. Yield (t)	10.34	15.23	6.2	21.7	18.68	14
Mkt yield (%)	76	87	61	83	95	81
Juice (%)	24	13	39	17	5	4
Output (£/ha)	12,883	18,661	8,016	26,730	22553	17602
Cost of sprays (£/ha)	295	335	229	756	385	400
Other costs (£/ha)†	9,258	11,657	7,201	15,224	13,280	9,324
Net margin (£/ha)	3,344	6,624	585	10,750	8,889	6,038

† Estimated from data collected as part of DEFRA funded project 'Economics of Organic Top Fruit Production' (OF0305)

Objective 1b: Identification of products to enhance apple leaf rotting in the autumn

SUMMARY (OBJECTVE 1b, FINAL REPORT)

Five separate experiments, the latter two at each of two sites, were conducted to test alternatives to urea for post harvest treatment to encourage rotting of apple leaves on the surface of the ground in the orchard post harvest. Fiesta leaves collected from an organic apple orchard before leaf fall were dipped in solutions of the test treatments in December, then held on the surface of the ground in batches of 30 in the test orchard. The numbers of leaves than disappeared subsequently due to degradation was assessed at intervals during the dormant period following treatment. The main conclusions were as follows:

- None of the treatments evaluated at standard rates were as consistent or as effective in encouraging leaf decay as urea.
- Nugro applied at an equivalent N content (25,000 ppm) to urea (62 times normal rate) was as effective as urea showing that N content was the important factor in leaf rotting.
- Sea Vigour (Fish oil) and Nugro (4000 ppm N = ten times normal rate) encouraged leaf rotting compared to the untreated in some seasons and may be worth including as post harvest pre leaf fall treatments.
- Compost tea (bacterial or fungal) was completely ineffective and may have delayed leaf rotting.

INTRODUCTION (OBJECTVE 1b, FINAL REPORT)

Apple scab overwinters as the sexual state on leaves on the orchard floor. In spring during rain ascospores are released from the leaf litter to initiate new infections on the developing leaves on the trees. Apple scab can also overwinter on trees as wood scab or as mycelium on the base of shoots or on bud scales but leaf litter on the orchard floor is probably the major source of inoculum in spring. Elimination of overwintering inoculum is one of the key factors in the integrated approach to scab control. In conventional production a spray of 5% urea is applied post harvest before leaf fall to reduce or eliminate the overwintering inoculum. The urea acts in two ways (1) directly on the scab fungus by interfering with the formation of the sexual state and (2) by encouraging colonisation of the fallen leaves by microorganisms, which initiate rotting and make the leaves more palatable to earthworms (Burchill et al, 1965; Burchill & Cook, 1971). Unfortunately use of urea is not permitted in organic production. The purpose of this work was therefore to identify alternatives to urea which could be used in organic production.

METHODS AND MATERIALS (OBJECTVE 1b, FINAL REPORT)

Five separate experiments were conducted to test alternatives to urea for post harvest treatment to encourage leaf rotting.

In the first experiment, leaves were collected from the experimental Fiesta orchard at Oakwood farm, Robertsbridge in the first week of November 2000 and stored at 4 ºC in a

fridge until required. Leaves were also collected and similarly stored from a conventionally sprayed Fiesta orchard (Wiseman IPM trial) at East Malling. On 14 December, aqueous solutions were prepared for dipping treatments (table 1b.1). Four replicate nets of 30 leaves from the organic Fiesta at Oakwood farm were dipped into each solution for half a minute, stirring to ensure thorough mixing. The leaves in their nets were allowed to dry overnight. Four replicate nets of leaves from each orchard were left untreated. The following day, they were spread in batches of 30 on the surface of the ground herbage under the trees in the organic Fiesta orchard at Oakwood farm in a randomised block design. Each batch (a plot) was held in place by plastic rigid netting which was secured to the ground by metal pins. The number of leaves remaining under each net was assessed on 16 January, 16 February and 28 March 2001 and mean values calculated.

Similar methods were used for the second and subsequent experiments. Leaves were collected from the experimental Fiesta orchard at Oakwood farm, Robertsbridge in the first week of November 2001 and stored at 4 ºC in a fridge in until December. Leaves were dipped on 17 December (Table 1b.2) and were set out in the organic Fiesta orchard at Oakwood farm the following day. The number of leaves remaining were assessed on 18 January, 11 February and 5 March 2002.

For the third experiment, leaves were collected from the same Fiesta orchard at Oakwood farm in the first week of November 2002 and treated on 11 December 2002 (Table 1b.3). The number of leaves remaining were assessed on 23 January and 28 February 2003.

The forth and fifth experiments, in winter 2003/04 and 2004/05 respectively, were each done at two sites, Oakwood Farm, Robertsbridge, and in the VF plots at East Malling Research. Leaves from the organic Fiesta from Oakwood Farm were used at both sites. Treatments applied are shown in Table 1b.4 and 1b.5 below.

RESULTS (OBJECTVE 1b, FINAL REPORT)

In the first experiment, the number of untreated leaves from the organic orchard remaining declined steadily between January and March (Table 1b.1). Those from the non-organic orchard at East Malling appeared to decay at a greater rate. The slower rate of disappearance of the organic leaves may have been because they contained a lower level of N or because they were contaminated with sulphur. The urea and the Nugro - high concentration (at the same concentration N as the urea of 25,000 ppm) treatments greatly accelerated the rate of disappearance of the leaves, indicating that the nitrogen concentration was the key factor in encouraging leaf rotting. Maxicrop, Nugro at the lower concentration and Digester appeared to slightly increase the rate of disappearance but the compost tea appeared ineffective. Sulphur, which is a general biocide and therefore may have affected the build up of microorganisms on the leaves and hence leaf rotting, did not affect the rate of decline of the leaves from the organic orchard.

In the second experiment, mild, wet weather conditions were very favourable for leaf rotting during the 2001/2002 winter. For all of the treatments almost half the leaves had rotted by the end of the first month after treatment (Table 1b.2). In the previous years experiment, only 10% of the leaves had rotted over a similar period. Consequently, by the next assessment on 11 February almost all the leaf material had rotted and it was not possible to distinguish between the effects of treatments as any effects were masked by the rapid natural rate of rotting. Thus, the relative effects of the treatments could not be determined.

Leaf rotting was also very rapid in the third experiment, even on the untreated, such that on most treatments most of the leaves had disappeared by the first assessment in late January (Table 1b.3). Liquid Vinasse (sugar beet waste) and Nugro (1600ppm N) appeared to delay

rotting. By the second assessment in late February most of the leaves had disappeared and there were no differences between treatments. Leaf rotting was too rapid in this experiment to distinguish treatment effects.

In 2003 experiments were conducted at two organic sites to increase the chances of obtaining differences between treatments. Experiment one had demonstrated that the concentration of nitrogen was the key factor in urea and Nugro (25,000ppm N rate) that resulted in rapid leaf rotting. Previous studies by Burchill ( ) demonstrated that the high nitrogen encouraged microorganisms to colonise the leaves and accelerate rotting. An alternative approach to the use of high nitrogen products would be to apply microorganisms directly by the use of compost tea. These products (bacterial and fungal) were therefore included in experiments in 2003. At the Oakwood site after one month, most of the leaves treated with urea had rotted (Table 1b.4). Over half the leaves treated with Nugro (4000ppm N) or Fish oil had rotted, whereas very little rotting had occurred in leaves treated with compost tea or left untreated. By the second assessment in February almost all leaves had rotted in all treatments apart from compost tea where around 25% of leaves were left. The compost tea treatments appeared to delay rotting,, but at this site natural decay of leaves over the winter was sufficient to result in minimal leaf litter remaining at bud burst in March. By contrast at the East Malling site, after one month little rotting had occurred in any of the treatments, including urea. After two months some rotting had occurred in leaves treated with urea or Nugro, but practically all leaves remained in the untreated plots or those treated with Fish oil or compost tea. No further assessments were carried out, but observations in March and April indicated that substantial numbers of leaves remained in all plots. Reasons for the poor leaf rotting at this site were not clear. Earth worm casts were abundant in the orchard, indicating that earth worms were active, but appeared to show no interest in the treated leaves.

In 2004 the experiment were repeated at the two sites. Compost tea was omitted, and Nugro at two rates (4000ppm N and 1600ppm N) included. Autumn /winter 2004 / 2005 was relatively dry and leaf rotting slower than in previous years. At the Oakwood site, after approximately six weeks almost all leaves had rotted in the urea, Nugro (4000ppm N) and Fish oil treated plot (Table 1b.5), compared to the untreated and Nugro (1600ppm N) treated plots. By mid March (bud burst) only a few leaves remained in the untreated and Nugro (1600ppm N) plots. Leaf rotting was much slower at The East Malling site, particularly in the untreated leaves, where over 50% of the leaves remained in mid March. Rotting was most rapid in plots treated with urea or Fish oil. In contrast to the Oakwood site, there was no difference in leaf rotting between the two rates of Nugro.

DISCUSSION (OBJECTVE 1b, FINAL REPORT)

It is clear from these results that the rate of leaf decay varies greatly between seasons, depending on temperature and more important rainfall during the dormant period, and also between sites. In mild wet winters as in 2002/2003 and 20003/2004, at the Oakwood site leaf rotting was relatively rapid in the untreated plots such that most leaves had disappeared by bud burst. Thus in most seasons here treatments to encourage leaf rotting, other than mowing to shred leaves may not be necessary. By contrast, at East Malling, rotting in the untreated plots was considerably slower than in treated plots, such that more than half the leaves remained at bud burst. Treatments to encourage leaf rotting would be of great benefit in minimising scab inoculum for the next season. None of the treatments evaluated at their normal rates were as effective or consistent as urea in encouraging leaf rotting. Applying Nugro, which has the highest N content of organic approved foliar feeds, at 62 times its normal rate to achieve an equivalent N content to urea at 5% (25,000ppm) resulted in

accelerated leaf decay similar to urea, indicating that N content is the critical factor. Such a rate of use however, would be excessively expensive. Nugro at ten times the normal dose and Fish oil did encourage leaf rotting, although not as consistently as urea, and maybe worth considering as treatments especially if combined with mechanical methods such as leaf shredding. Urea also has the additional effect of preventing formation of the scab sexual fruiting bodies (pseudothecia) during the dormant period such that ascospore dose is considerably reduced on any leaves remaining in spring. The effect of the alternative treatments on the scab sexual state was not investigated in this study.

CONCLUSIONS (OBJECTVE 1b, FINAL REPORT)

- None of the treatments evaluated at standard rates were as consistent or as effective in encouraging leaf decay as urea.
- Sea Vigour (Fish oil) and Nugro (4000 ppm N = ten times normal rate) encouraged leaf rotting compared to the untreated in some seasons and may be worth including as post harvest pre leaf fall treatments.
- Compost tea (bacterial or fungal) was completely ineffective and may have delayed leaf rotting.

REFERENCES (OBJECTVE 1b, FINAL REPORT)

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Table 1b.1. Number (maximum=30) of leaves remaining following treatment with various chemicals in December 2000 in the leaf rotting experiment Oakwood Farm in winter 2000/2001

Treatment	Concentration (amount/litre	16 Jan 2001	16 Feb 2001	28 Mar 2001
Untreated (Oakwood)	-	26.0	14.0	0.4
Untreated (EM)	-	25.8	8.1	0.3
Urea	50 g	21.3	1.9	0
Compost Tea	1:10 dilution	27.9	12.3	0.5
Nugrow (400ppm N)	5 ml	25.6	7.8	0.1
Nugrow (25000ppm N)	312.5 ml	11.9	0.6	0
Maxicrop original	1:10 dilution	25.6	10.9	0.4
Digester	1:10 dilution	27.4	8.1	0
Sulphur	5.6 ml	27.4	12.6	0.4

Leaves treated and laid out in the orchard 14-15 December 2000. numbers of leaves remaining assessed monthly.

Table 1b.2. Number (maximum=30) of leaves remaining following treatment with various chemicals in the leaf rotting experiment Oakwood Farm in winter 2001/02

Treatment	Concentration (amount/litre)	18 Jan 2002	11 Feb 2002	5 Mar 2002
Untreated	-	17.8	0.4	0
Urea (5%)	50 g	12.1	0.2	0
Nu-gro (400ppm N)	5 ml	20.6	1.5	0.3
Nu-gro (1600ppm N)	20 ml	18.6	1.8	0
Nu-gro + Digester	20 ml + 100 ml	15.9	1.5	0
Digester	100 ml	16.6	0.8	0
Maxicrop Original	100 ml	20.0	1.8	0.1
Sea Vigour Fish Oil	12.5 ml	18.6	2.1	0
Sea Vigour Fish Oil (high rate)	50 ml	14.5	1.0	0
Liquid Vinasse	50 ml	16.5	1.3	0

Leaves treated and laid out in the orchard 17-18 December 2001. numbers of leaves remaining assessed monthly.

Table 1b.3. Number (maximum=30) of leaves remaining following treatment with various chemicals in the leaf rotting experiment Oakwood Farm in winter 2002/03

Treatment	Concentration (amount/litre)	23 Jan 2003	28 Feb 2003
Untreated	-	1.3	0.1
Urea (5%)	50 g	0.3	0
Nu-gro (1600ppm N)	20 ml	14.6	1.6
Nu-gro + Digester	20 ml + 100 ml	1.9	0
Digester	100 ml	3.6	0
Sea Vigour Fish Oil	12.5 ml	4.0	0.2
Sea Vigour Fish Oil (high rate)	50 ml	5.5	0.4
Liquid Vinasse	50 ml	9.1	1.9
Compost tea	undiluted	2.5	0.1

Leaves treated and laid out in the orchard in December 2002. numbers of leaves remaining assessed after one and two months

Table 1b.4. Numbers (maximum=30) of leaves remaining following treatment with various chemicals in the leaf rotting experiments at Oakwood Farm and East Malling Research in winter 2003/04

Treatment	Concentration (amount/litre)	6-7 Jan 2004	3-4 Feb 2004
Oakwood farm			
Untreated	-	21.3	2.6
Urea (5%)	50 g	5.5	0.8
Nu-gro (4000ppm N)	50 ml	11.3	1.1
Fish oil	200 ml	13.3	1.8
Compost tea (bacterial)	undiluted	24.3	8.0
Compost tea (fungal)	undiluted	22.0	6.0
Village field, East Malling			
Untreated	-	29.9	28.8
Urea (5%)	50 g	28.4	20.1
Nu-gro (4000ppm N)	50 ml	27.6	18.0
Fish oil	200 ml	30.0	29.5
Compost tea (bacterial)	undiluted	29.4	28.2
Compost tea (fungal)	undiluted	29.4	28.0

Leaves treated and laid out in the orchard in December 2003. Numbers of leaves remaining assessed after one and two months

Table 1b.5. Numbers (maximum=30) of leaves remaining following treatment with various chemicals in the leaf rotting experiments at Oakwood Farm and East Malling Research in winter 2004/05

Treatment	Concentration (amount/litre)	10-11 Feb 2005	15-16 March 2004
Oakwood farm			
Untreated	-	12.8	5.1
Urea (5%)	50 g	0.1	0
Nu-gro (4000ppm N)	50 ml	2.5	0.4
Nu-gro (1600ppm N)	20 ml	12.3	4.6
Fish oil	200 ml	5.0	1.4
Village field, East Malling			
Untreated	-	25.5	17.3
Urea (5%)	50 g	6.0	3.1
Nu-gro (medium rate)	50 ml	13.0	6.1
Nu-gro (low rate)	20 ml	13.5	6.5
Fish oil	200 ml	4.4	1.9

Leaves treated and laid out in the orchard in December 2004. Percentage of leaves remaining assessed after one and two months

Objective 1c: Testing products for sooty blotch control

SUMMARY (OBJECTIVE 1c, FINAL REPORT)

In 2003, a single replicated small plot orchard experiment was done to evaluate a range of products for control of sooty blotch (*Gloeodes pomigena*) in organic apple production. The experiment was located in a mature Jonagold apple orchard at Oakwood Farm, Robertsbridge, East Sussex. Treatments were a programme of sprays of copper oxychloride, sulphur, kaolin or extract of coconut + citrus (Crop Life)+calcium carbonate applied on 4 occasions from late July to September using a mist blower at 1000 litres per hectare. A randomised block design with 5 replicate single tree plots was used. None of the treatments controlled sooty blotch. The kaolin treatment whitened the trees and left an unsightly deposit on the fruits at harvest.

INTRODUCTION (OBJECTIVE 1c, FINAL REPORT)

Sooty blotch (*Gloeodes pomigena*) causes sooty-like discoloration on near-mature fruit and, although superficial, make the fruit unsightly, thus downgrading it and reducing saleability. The disease is prevalent in organic orchards. The fungus overwinters on twigs of various woody plants in the hedgerow and windbreak and on apple twigs. In spring, pycnidia (fruiting bodies) on wild plants and apple twigs produce large numbers of spores (conidia) that ooze out and are spread by rain splash or wind blown mist in orchards in spring and early summer to autumn. The fungus first infects apple twigs and from these infections fruit are colonised from late June/early July onwards. Cool, humid weather (optimum 18^{o}C) is essential for disease development. The fungus can also continue to develop in store. Since sooty blotch is an epiphytic fungus only colonising the surface of various woody hosts without causing visible symptoms until colonising the fruit, monitoring it in the orchard is difficult. In conventional production sooty blotch is easily controlled by applications of fungicides in June and July. The purpose of this experiment was to evaluate alternative products which could be used to control the disease in organic production. In trials in the USA both sulphur and Kaolin have been reported to give control. Crop Life contains a mixture of coconut and citrus extracts which have been reported to be of some benefit in sooty blotch control in trials in Europe.

METHODS AND MATERIALS (OBJECTVE 1c, FINAL REPORT)

In 2003, a single replicated small plot orchard experiment was done to evaluate a range of products for control of sooty blotch (*Gloeodes pomigena*) in organic apple production. The experiment was located in a mature Jonagold apple orchard at Oakwood Farm, Robertsbridge, East Sussex. The orchard had Ida Red pollinators. The tree spacing was 3.1m between trees in the row and 4.5m between rows. Treatments were a programme of sprays of 4 different chemical products applied on 24 July, 7 August, 20 August, 11 September 2003 (Surround was not applied on this date), and an untreated control. Sprays were applied using a mist blower at 1000 litres per hectare are shown in Table 4. Single tree plots were used. Trees were chosen so they had 50-100 fruits per tree. Each treatment was replicated 5 times in a randomised block design.

Table 1c.1. Treatments applied in the sooty blotch experiment 2003.

Product	Active ingredient	Product rate per hectare
1. Untreated	-	-
2. Cuprokylt	Copper oxychloride	0.45 litres
3. Headland Sulphur 80 SC	Sulphur	10 litres
4. Surround	Kaolin	50 kg
5. Crop Life + calcium carbonate	Extract of citrus and coconut	300ml + 250gm $CaCO_3$

RESULTS (OBJECTVE 1c, FINAL REPORT)

Monitoring of fruits in an adjacent Fiesta orchard indicated that the sooty blotch first appeared on fruit in late July 2003. Therefore sooty blotch was already present before the first spray was applied. At harvest on 24 September 2003 the incidence of sooty blotch on a sample of 50-100 fruit per plot was assessed as slight, moderate, severe. By harvest up to 80% of fruit were infested by sooty blotch (Table 31). The lowest infestation of sooty blotch occurred on trees left untreated or sprayed with low rate Cuprokylt.

Table 1c.2. Incidence of sooty blotch on fruit at harvest on 24 September 2003 in the sooty blotch trial in the Jonagold orchard at Oakwood farm

Product	% fruit with sooty blotch	% fruit with severe sooty blotch
1. Untreated	67.3	10.2
2. Cuprokylt	74.8	11.0
3. Sulphur	86.3	22.8
4. Surround	83.1	23.3
5. Crop Life + calcium carbonate	81.5	14.4

As the first spray wasn't applied until after sooty blotch infection came in, this may explain why none of the treatments were effective but not why the lowest infection was present on the untreated. Spraying aqueous sprayate to the trees may have even benefited the sooty blotch in the hot, dry conditions that prevailed. It was obvious that the sooty blotch was developing very successfully under the kaolin treatment. This treatment will not be tried again because the trees and the fruit were whitened by the treatment and it was impossible to remove the deposit making the apples unsaleable. Moreover, the apples were unpleasant to harvest the deposit coming off on the pickers hands and causing nasal irritation.

CONCLUSIONS (OBJECTVE 1c, FINAL REPORT)

Programmes of sprays of copper oxychloride, sulphur, kaolin or extract of coconut + citrus (Crop Life)+calcium carbonate applied on 4 occasions from late July to September using a

mist blower at 1000 litres per hectare failed to control sooty blotch (*Gloeodes pomigena*). The kaolin treatment whitened the trees and left an unsightly deposit on the fruits at harvest.

Objective 2: To identify 4-6 varieties of apple of low susceptibility to diseases that have high fruit quality, a range of seasons (storage potentials) and markets (dessert, culinary, processing, juicing) and are suitable for organic production.

INTRODUCTION (OBJECTIVE 2, FINAL REPORT)

Nearly all of the popular commercial varieties of apples, grown currently for the dessert, culinary and processing markets in the UK, exhibit susceptibility to the diseases scab (*Venturia inaequalis*) and mildew (*Podosphaera leucotricha*). Many are also sensitive to damaging pest species. Although organic fruits of these varieties are in demand by the major retailers, their production in the UK is very difficult. Very frequent sprays of sulphur give only poor disease control and if use of copper fungicides is withdrawn, the problems will exacerbate. It is argued that if the public perception of organic apples, as fruits from trees that are largely unsprayed, is to be achieved, alternative varieties that show resistance or tolerance to these damaging diseases are required. However, suitable resistant varieties must also be of good quality (flavour, texture, juiciness) and appearance (colour and skin finish) if they are capture a significant proportion of the current apple market.

Objective 2 of this project was to screen and evaluate the apple varieties available throughout the world in an attempt to identify 4-6 varieties showing significant promise for organic production in UK environmental conditions.

The work breakdown for this objective consisted of the following sub-objectives:

Years 1-2 (Preliminary screening)
2.1 Determine selection criteria for the varieties
2.2 Create a database containing information on promising varieties for organic production
2.3 Acquire fruit samples of promising varieties
2.4 Conduct preliminary taste and processing tests
2.5 Reject unsuitable varieties
2.6 Short-list 20 most promising varieties
2.7 20 most promising varieties short-listed

Years 1-3 (Establish field experiment)
2.8 Acquire bud wood of promising varieties
2.9 Bench graft in winter of year 1
2.10 Raise trees in polytunnels at East Malling
2.11 Plant replicated experiment at East Malling in second winter
2.12 Spray half the experiment with sulphur
2.13 Assess pest and disease levels during establishment
2.14 Field experiment established

Years 3-5 (Evaluate varieties)
2.15 Conduct taste tests on fruit in year 3 where available
2.16 Assess pest and disease levels in June and at harvest
2.17 Assess agronomic performance
2.18 Conduct taste and processing tests

2.19 Conduct preliminary storage tests
2.20 Collate and evaluate data
2.21 Identify best varieties
2.22 4-6 suitable varieties identified

MATERIALS AND METHODS (OBJECTIVE 2, Sub-objectives 2.1-2.11, FINAL REPORT)

Objective 2.1: Determine selection criteria for the varieties

At the outset of the project, a draft list of possible selection criteria for organic apple varieties was drawn up by staff at HRI and circulated to relevant members of the consortium. All possible attributes were listed and the recipients were asked to prioritise these. Further discussions on these priorities were undertaken during meetings with the Consortium.

Objective 2.2. Create a database of information on more than 100 possible varieties/selections

Information on traditional and new varieties of apples was collected using;
a) knowledge of the scientists and collaborators involved in the project
b) information from the National fruit Collection at Brogdale, Faversham, Kent
c) literature searches
d) networks of contacts with fruit breeders throughout the world
e) measurements and records taken on varieties growing at HRI-East Malling and from an APRC-funded variety trial planting at Peter Hall's orchard at Poultry farm, Marden, Kent. This included observations on the incidence of scab, mildew and other diseases and pests. Estimates were also made of yields and tree vigour and habit (agronomic performance).

The information was collated for each variety/selection and photographs of as many varieties as possible were taken throughout work on the project.

Objective 2.3. Acquire fruit samples of as many varieties as possible with potential for organic apple production

Fruit samples (a minimum of 2kg/variety) of promising apple varieties were acquired from:
a) fruiting trees growing at HRI-East Malling which were managed (sprayed) according to organic protocols or unsprayed.
b) fruiting trees growing in a small orchard in Kent, where no agrochemical sprays were applied.
c) fruiting trees within the National Apple Collection, sited at the Brogdale Trust, Faversham, Kent.
d) Fruit breeders and those involved in apple variety selection and evaluation in France, Germany, Poland, Italy, Netherlands, Czech Republic and the USA.

Attempts were made to obtain the samples at the most appropriate time of harvest but this was not always fully successful with the fruits obtained from abroad.

Objective 2.4. Conduct preliminary taste and other evaluations by marketing members of the consortium

During the first two years of the project (2000 - 2001), at appropriate timings during the harvesting season, quality evaluations on the varieties acquired were conducted in the tasting booths at HRI-East Malling. Prior to conducting the evaluations, post harvest assessments were made of fruit weight, diameter, pressure and sugar/starch content. The evaluations involved assessments of fruit appearance, firmness, texture(crispness), juiciness, acidity/sweetness, flavour size, shape, and overall acceptability. Each fruit sample was scored out of 4 for each criterion (see sensory profiling sheet in 1). Fruit samples of 110 dessert and 35 culinary varieties were assessed by an evaluation panel (comprising the marketing and retailing members of the consortium) during 2000. Having selected an initial list of 42 during the first year, repeat evaluations on these varieties were undertaken in 2001.

Objective 2.5. Reject unsuitable varieties &
Objective 2.6/7.Short list 20 most promising varieties

Using the results of the quality evaluations during 2000 and 2001, and information collected within the database, 26 dessert, 4 culinary and 2 dual-purpose varieties (32 in total) were identified as showing 'potential' for organic cultivation by the end of 2001, but it was decided that only 1 juicing, 23 dessert and 3 culinary varieties would be grafted to produce trees for inclusion in a replicated variety trial at East Malling (27 varieties in total). All other varieties initially evaluated during the project were rejected on the basis of inferior fruit quality (and/or other likely problems associated with cultivation under organic methods).

2.8 Acquire bud-wood
Graftwood was obtained for each of the 27 promising varieties chosen at the end of 2001. Most of the wood was acquired from plant breeding organisations abroad and it was necessary to seek agreement with the respective owners of Plant Variety Rights. Wood sourced from the UK was collected from the National Fruit Collections at Brogdale and also from several varieties at the APRC-funded variety trial at Peter Hall's farm at Poultry Farm, Marden, Kent.

2.9-10 Bench graft in winter of year 1 and raise trees in polytunnels
Bud-wood of the selected varieties was grafted onto two year old ex-Saturn trees (20 trees of each variety on M9 rootstock) during winter / early spring of 2001 in order to establish vigorous and strong growing, well feathered trees as quickly as possible. The original plan had been to use bench-grafts, but it was agreed that using 2-year old ex-Saturn trees would produce stronger trees of better quality.

2.11 Plant replicated experiment at EM in second winter
The trees were planted in a fully replicated variety trial consisting of 6 blocks of 3-tree plots on registered (July 2002) organic land at HRI East Malling's Village Field site (VF216) (see Appendix 2 for plot map).

RESULTS (OBJECTIVE 2, Sub-objectives 2.1 – 2.11, FINAL REPORT)

Objective 2.1. Determine selection criteria for the varieties

Following discussions with members of the consortium, it was agreed that, where possible, a successful dessert apple variety for organic production should have a combination of the following attributes for volume sales by the major multiple retailers in the UK:

a) a good balance of fruit quality characteristics. These include appearance (colour and shape), firmness, juiciness, crispness, and taste (flavour and sugar/acid balance). The importance of fruit quality was stressed where fruits were to be destined for sale via the multiple retailers.
b) resistance or tolerance to scab and mildew
c) no great sensitivity to important apple pests, particularly those for which no acceptable control measures exist under organic protocols
d) no great sensitivity to other apple pathogens, such as canker (*Nectria galligena*)
e) ability to yield precociously, productively and consistently, with well-sized fruit (>60mm).
f) suitability for short or long term fruit storage (depending on season).

Objective 2.2. Create a database of information on more than 100 possible varieties/selections

During the first year of the project (2000), a database containing information on 115 dessert and 39 culinary varieties was constructed using information obtained locally and from throughout the world. Each apple variety listed on the database contained information on; origin (i.e. where produced), type (i.e. dessert or culinary), picking date, season (i.e. of consumption), storage recommendations, appearance of fruits, eating / cooking quality of fruits, cropping, vigour and habit of tree, resistance / tolerance to diseases and pests and any other information deemed relevant. Where possible, the database also contained a colour illustration of the variety. The database was revised and updated throughout the life of the project and was initially made available to consortium members in electronic format.

Objective 2.3. Acquire fruit samples &
Objective 2.4. Conduct preliminary taste and other evaluations by marketing members of the consortium

During 2000, fruit samples of 110 dessert varieties were obtained for evaluation by the quality assessment panel. A further 35 varieties with culinary potential were obtained for culinary evaluation. Fruits of the majority of the varieties were obtained from UK sources. However, samples of approximately 30 varieties were obtained from colleagues abroad. The quality evaluations were conducted on 12 separate dates between August and December using the tasting booths at HRI-East Malling.

Fruit samples of 42 dessert varieties and 6 culinary varieties were obtained for repeat evaluations during 2001. Once again, fruits of most of these varieties were obtained from UK sources. However, samples of 9 varieties were obtained from contacts abroad. During the second year (2001) sub-objectives 2.3 – 2.7 were repeated for the 42 varieties of apple (dessert and processing) in order to 'fine tune' the selection and ensure the choice of potential varieties made during the first year would remain consistent. It was also necessary to eliminate some of the varieties on the list in order to achieve a list of potential cultivars near the target number of 20.

Due to the greatly reduced number of apple varieties undergoing assessment in the second year of the project, compared to the initial screening of over 100 varieties in year 1, samples destined for evaluation were either delivered or posted out for assessment by the taste panel. As with the assessments made during year 1, dessert varieties received scores for aroma,

firmness, crispness, juiciness, sweetness, acidity, flavour and appearance. Culinary varieties were assessed for their processing potential at Fourayes farm where pie-making tests were carried out on each cultivar. Criteria for selection in this case focussed on the flavour and consistency of the apple after cooking.

A list of all the varieties evaluated during 2001 is given below:

Early Season: Alkmene, Ceeval, E1120, Julia, Piros, Rebella, Reka, Retina

Mid Season: Ariwa, D3, D7, Judeline (juicing), Nova, Pimona, Red Fortune, Reglindis, Ribston Pippin, Rubinola, Topaz

Mid-Late Season: Adams's Pearmain, Bohemia, DL11, DL13, HY32.2, Liberty, Priscilla, Rajka, Realka, Reanda, Red Falstaff, Resi, Rewena, Rosana, Rubinstep, Vesna

Late Season: Ashmead's Kernel, Delorina, Florina, Goldrush, Pilot, Pinova, Winston Red Sport

Culinary: Bountiful, Early Victoria, Edward VII, Encore, Howgate Wonder, Pikant

Where necessary, several picking dates of each variety were used in order to establish the optimum harvest date. Measurements carried out on the apples after harvest included fruit size, weight, firmness and soluble solids, the results of which were added to the existing variety database. Where fruit samples could not be delivered or posted immediately, they were held in temporary air storage at 1°C.

Objectives 2.5 and 2.6. Reject unsuitable varieties and select 20 most promising ones for further evaluation.

Very few varieties fulfilled all of the selection criteria. However, following meetings between staff at HRI/HDRA and the members of the quality evaluation panels, the following preliminary selection of approximately 27 varieties was made;

Early Season: Discovery, Rebella, Worcester Pearmain

Early – Mid: Ceeval

Mid Season: Ariwa, D3, Ecolette, Rubinola, Topaz, Santana

Mid-Late: Bohemia, DL11, Liberty, Rajka, Red Falstaff, Resi, Rubinstep

Late Season: Delorina, Florina, Goldrush, Pilot, Pinova

Culinary: Edward VII, Howgate Wonder, Encore, Pikant

Juicing: Judeline

In addition to those varieties listed above, the panel agreed to continue assessments of the early season variety Julia, mid- season varieties Pimona, Nova and Ahra, and mid-late season varieties Adams's Pearmain, DL13, Priscilla and Vesna. Trees of these additional varieties were not, however, included in the replicated trial.

Objective 2.8 Acquire graftwood

Graftwood of the chosen varieties was obtained during winter / early spring of 2001 from the national fruit collections at Brogdale, the variety trials at Poultry Farm or from experimental trees at Rock's Farm (HRI-East Malling). Graftwood for the varieties Resi and Rebella was also obtained from Germany, Ariwa was obtained from France and Rubinstep from Czechoslovakia.

Objective 2.9 / 10 Bench graft in winter of year 1 & plant replicated experiment at EM in second winter

The selected varieties were raised via grafting onto two-year old ex-Saturn trees during winter / spring 2001. Although the objective was to raise 20 trees of each variety, some varieties did not graft successfully and tree numbers available for planting therefore varied greatly. Additional trees were obtained by grafting onto ex-Saturn trees in March 2002 in order to meet the final requirement for 18 trees of each variety. To provide a balanced plot design, additional Red Falstaff trees (not grafted on to Saturn) were required to fill gaps in the planting. The trial orchard consisted of a replicated block design (three tree plots replicated six times) planted onto registered (July 2002) organic land at East Malling's Village Field site, VF216. See plot plan, Appendix 2.

MATERIALS AND METHODS (OBJECTIVE 2, FINAL REPORT)

<u>Sub objectives 2.12 – 2.19</u>

2.12 Spray half the replicated trial of apple varieties with sulphur

Sulphur was applied to blocks I, IV & V (half the experiment) during 2002-2004 (Table 2.1)

Table 2.1. Applications to VF216 (blocks I, IV & V) 2002-2004

Product	Application date 2002	Application date 2003	Application date 2004	Rate	Spray volume
Lawes Compost		31 March		250K	
Sulphur 800g/l SC	3 April	24 March	31 March	5L	500L
Sulphur 800g/l SC	15 April	9 April	14 April	5L	500L
Sulphur 800g/l SC	2 May	24 April	7 May	5L	500L
Sulphur 800g/l SC	10 May *	9 May	12 May	5L	500L
Bactura (*BT*)	-	22 May	-	0.75L	1000L
Sulphur 800g/l SC	18 June	22 May	21st June	5L	500L
Sulphur 800g/l SC	30 June	2 June	16 July	5L	500L
Sulphur 800g/l SC	14 July	23 June	30 July	5L	500L
Sulphur 800g/l SC	24 July	3 July		5L	500L
Sulphur 800g/l SC	5 August	11 July		5L	500L
Sulphur 800g/l SC	15 August	25 July		5L	500L
Sulphur 800g/l SC		4 August		5L	500L

*Due to wet weather in 2002, two sprays were missed during the period of end May – early June.

2.13 Assess pests and diseases during establishment

It was agreed that only one pest and disease assessment would be undertaken during 2002 since the trees had not long been planted. An assessment of leaf scab, secondary mildew, canker and rosy apple aphid was made on 16th September 2002. Each tree was examined for signs of canker and rosy apple aphid and one shoot on each tree was examined for signs of mildew and scab. Symptoms of mildew and scab were scored by severity (0= none, 4 = severe). Canker and rosy apple aphid infestations received one score for each symptom found. It was noted that some varieties had made very poor growth and there was little vegetation available to examine. Pest and disease incidence was generally low (see results section) due to the infancy of the planting.

2.14 Field experiment established

Most of the trees on VF216 appeared to have established well by the end of 2002, although some varieties had naturally grown more vigorously than others. Very weak growing trees and those lost to canker were re-grafted or replaced by Will Sibley during February 2003. The planting plan and block arrangement of the variety planting on VF216 is shown in Appendix 2.

2.15 Conduct taste tests on fruit in year 3 where available

No fruit was available for tasting from VF216 in 2002. However, fruit samples continued to be sourced from other areas (Brogdale, Poultry Farm, Rocks Farm and Wiseman plots at East Malling) for taste panel assessments at the Sainsbury's Centre (see section 2.18 and results).

2.16 Assess pest and disease levels in June and at harvest (Years 4-5)

Year 4

Pests and diseases were assessed on 18th June 2003. Each tree was examined for signs of rosy apple aphid and green apple aphid. One shoot on each tree was examined for symptoms of primary mildew and leaf scab. Each tree received a score for every aphid infestation found. Symptoms of mildew and scab were scored by severity (0=none, 1=slight, 2=moderate, 3 = bad, 4=severe). Some of the weaker varieties continued to grow poorly with little vegetative growth, which made assessment difficult. Several varieties had also been re-grafted owing to losses through canker or failure to establish. Aphid infestations were apparent on some varieties and most varieties showed symptoms of mildew (see results section). No scab was found on any of the varieties during June but leaf samples of each variety were collected on 21st October for late-season scab assessment. Due to the relatively low incidence of pests and diseases, it was agreed that a further assessment at harvest would not be necessary.

Year 5

An assessment of pests and diseases was made on 15 July 2004. Each tree was examined for signs of rosy apple aphid and green apple aphid and the number of trees showing signs of infestation were recorded. Ten leaves on each tree were examined for symptoms of secondary mildew and leaf scab (180 leaves total). The results from both years are presented in Table 2.2 (see results, section 2.16).

2.17 Assess agronomic performance

Shoot growth records were taken at the end of December 2002, 2003 and again during December 2004. The measurements were recorded (in decimetres) of the current season's

growth for each of the central tree per plot in every block (6 trees of each variety in total). The total new growth per tree was then divided by the number of new shoots per tree to achieve a mean value. The total mean values from each tree per plot were then totalled from all 6 blocks to give an overall value for shoot growth per variety. The results are presented in Table 2.3 (results section 2.17).

An assessment of tree fruit precocity was made on 20th August 2003. Notes on tree form and habit were also taken. Scores were allocated per plot for precocity (0 = no fruit, 2 = 1-10 fruits, 3 = > 10 fruits). The score from each plot, (per block), was then totalled up for the whole orchard (x6 blocks). Some of the trees had been hand thinned during June to improve fruit size. The following year, an assessment of floral precocity was undertaken on 29th April 2004. This measured the bloom density and flowering stage of each variety per block. Bloom density ratings were recorded as the amount of blossom present (5 = very heavy, 4 = heavy, 3 = moderate, 2 = light, 1 = very light / none). Flowering stage was recorded from Green cluster / pink bud / percentage bloom from 10% - full bloom / petal fall. Where there were slight variations in flowering stage for the same variety between plots, the most common stage was recorded. Given these measurements, it was possible to place each of the varieties within a preliminary pollination group (1 = very early flowering – 6 = very late flowering). During 2004, an assessment of tree form, habit and vigour, and overall yield (crop load) was carried out at harvest (18th September 2004). (See results section 2.17)

2.18 Conduct taste and processing tests
2002-2003

Availability of fruit
Although there were no fruits available from the new variety planting on VF216, fruit samples collected from the National Fruit Collections - Brogdale, Poultry Farm, Rocks Farm and East Malling plots (Wiseman) were used for taste panel evaluation at the Sainsbury's Centre. A limited quantity of fruit from most varieties on the trial plot VF216 was available for assessment during 2003. Fruit was also obtained from the National Fruit Collections (Brogdale), Poultry Farm (Marden), Rocks Farm (East Malling) and existing plots at East Malling. Several varieties were obtained from overseas. These included D3 (from Poland), DL11 (from France) and Rubinstep (from Czech Republic). There were sufficient fruits of varieties Ariwa, Resi and Rebella from trees on VF216, so it was not necessary to obtain these varieties from abroad, as had originally been planned.

Varieties assessed
It was agreed that the panel would concentrate on UK sourced fruit, supplied for tasting during 2002, with varieties sourced from abroad and early season UK varieties scheduled for assessment the following year (2003). These included Rebella, Ariwa, D3, Resi and Rubinstep and the early season varieties Discovery and Worcester Pearmain. In addition to this, most of the other varieties on the original short-list of 27 were also once again evaluated or reviewed, with the view to selecting the best 10 for final large-scale assessment in 2004. It was agreed that there were too many potential varieties for large-scale taste testing at the Sainsbury's Centre until a target number of 10 varieties could be selected. This allowed adequate numbers of fruits to be available for storage trials during 2002 and 2003 (see objective 2.19).

Varieties assessed in 2002:
Early season: Ceeval
Mid season: Rubinola, Ecolette, Rajka, Bohemia
Mid-late: Topaz, Pilot, Pinova, Red Falstaff
Late season: Liberty, Florina, Delorina

Varieties assessed in 2003:
Early season: Ceeval, Discovery, Worcester Pearmain
Mid season: Rubinola, Rajka, DL11, Rebella, Resi, Rubinstep
Mid-late: Pinova, Red Falstaff, Ariwa, Santana
Late season: Liberty, Florina, Delorina, D3 (Free Redstar)

Delivery of fruit
Fruit samples (30+ fruits of each variety) were supplied to Sainsbury's and Waitrose from August – October during 2002 and 2003. Following harvest, the apples were packed and sent via courier in batches of 2-4 varieties. It was occasionally necessary to hold fruit in storage at 1°C for a short time to await a convenient date for assessment.

Method of assessment
During the assessments, varieties were scored for texture qualities (including firmness, juiciness, crispness, toughness and flouriness), taste (sweetness and acidity) and physical appearance (shape and colour). They were also given an overall ranking for acceptability. The profile testing sheets used for assessment can be found in the Appendix 1.

A variety review meeting was held on 7th November 2003 to review the evaluations from the past two years and discuss each variety in detail. The meeting was attended by supermarket representatives involved in the taste testing and staff from HRI East Malling and HDRA. In addition to those varieties evaluated during the year, the panel also had the opportunity to sample and discuss any remaining dessert varieties from the original short-list, together with the culinary varieties Edward VII, Encore, Howgate Wonder and Pikant, to review their suitability for fresh sales. At the end of the meeting, the decision was taken to eliminate at least half of the dessert apple varieties from the short-list. The decisions were based on visual appearance and internal fruit quality (i.e. likely acceptability by consumers), also taking into account the performance of each variety in taste test evaluations during previous years. Having secured agreement from consortium members, the remaining 11 most promising varieties were put forward for final large-scale taste test assessment in 2004 (below).

Short-listed varieties for final large-scale taste test evaluation in 2004:

Early season

Discovery
Ceeval

Mid season

Rajka
Resi
Rubinola

Mid-late season

Red Falstaff
Ariwa
Pinova
Rubinstep

Late season

Liberty
Delorina

2004 (year 5) – Final large scale evaluation of promising varieties

Having arrived at a final short-list of 11 most promising apple varieties after four years of small-scale fruit quality evaluations, a schedule of evaluations was set up to have the short-listed varieties evaluated on a large scale at the Sainsbury's Centre in Holborn, London, during 2004. Over 100 fruits of each apple variety were supplied for these large-scale consumer taste-test evaluations. In most cases enough fruit was available from plots at East Malling Research, and also from the variety trial at Poultry Farm, Marden. However, it was necessary to request additional fruits of the variety Rubinstep from the Czech Republic, owing to low fruit numbers on VF216. Each apple variety was coded to avoid any consumer bias towards 'named' varieties.

Starch/sugar analysis and penetrometer tests were used to determine ripeness and fruits were harvested as soon as they were ready for immediate consumption. The programme of evaluations meant that two varieties were sent to Sainsbury's at a time for 'two-way' comparison testing. Each apple was labelled with the variety code and packed into secure boxes and dispatched via courier to Sainsbury's head office (next-day delivery). Evaluation of the varieties at Sainsbury's took place on the day of delivery, or, if this was not possible, the apples were held in cold storage and evaluated on the next convenient day. Small samples of each apple variety (10-15 fruits) were also boxed and sent to Waitrose headquarters at Bracknell for small-scale evaluation.

The product testing questionnaire which was used for each apple variety evaluation at the Sainsbury's Centre is shown in Appendix 3. Between 100 and 150 staff at the Sainsbury's Centre were asked to participate in the questionnaire, which involved sampling one apple (or piece of apple) each, and responding to questions about each variety on an internal on-line questionnaire. Participants were first asked which was their favourite type of apple (from a choice of conventional commodity varieties). This helped to gauge what proportion of the participants preferred each apple type (e.g. bi-coloured, russet, sweet, sharp etc). As expected, in most cases, crisp, sweet, bi-coloured apples such as Pink Lady, Gala and Braeburn were the most preferred options. Participants were then asked to try each of two organic apples in succession and give them an overall mark out of 10 (0= poor – 10 = extremely good). This was done to ascertain likely initial consumer reaction to the variety. The participants were then asked to rate the product on several characteristics including appearance, shape, colour, flavour, sweetness, sourness, texture, firmness, juiciness and crispness (again, giving an overall mark out of 10). They were then asked for any further comments about what they particularly liked / disliked about the product, how often they would eat the product and if they would buy it. At the end of the questionnaire, participants were asked which, of the two

apple varieties, they preferred. The overall results of the product tasting questionnaires are shown in Tables 2.9 and 2.10 (results section 2.18).

Evaluations at Waitrose were carried out using the standard sensory profiling sheet as used in previous evaluations. Varieties were scored for texture qualities, (firmness, juiciness, crispness, toughness, flouriness), taste (sweetness and acidity) and physical attributes (shape and colour). Each variety also received an overall ranking for acceptability.

2.19 Conduct preliminary storage tests

Air storage tests in 2002

In order to assess whether any of the promising varieties have adverse reactions to cold storage temperatures, preliminary storage tests were set up to look at the behaviour of apple varieties under different temperature regimes in basic air storage during 2002. Post harvest, varieties were sorted into crates and stored at three different air temperatures of 0-0.5°C, 1.5-2°C and 3°C until January 2003. Five fruits of each variety were removed in mid-November, mid-December and the end of January. Assessments of fruit firmness were made using an LRX texture analyser. Other measurements taken included weight, diameter, sugar (% soluble solids) and background colour (using a WorldWideFruit colour chart).

CA storage tests in 2003

Following the preliminary air storage trials in 2002, a basic CA storage trial was set up using fruit harvested during 2003 to observe the behaviour of each variety in controlled atmosphere conditions. Where sufficient fruit numbers were available, varieties were sorted into crates and stored in a low oxygen regime at (<1% CO2 + 2%O2) at 1.5-2°C. Assessments of fruit firmness, diameter, weight and sugar content (% soluble solids) and background colour were carried out at 2, 4 and 6 month intervals on a sample of 5 fruits of each variety. Any signs of physical deterioration or adverse reaction to cold temperatures / low oxygen were also recorded.

Storage tests during 2004

Due to the large numbers of fruits required for the product-tasting assessments at Sainsbury's during 2004, no fruits of the eleven selected varieties were available for further storage tests. However, a basic air storage regime was set up for limited numbers of Topaz fruits in November 2004, to see if eating quality of the variety improved during storage. Fruits were placed into air storage at temperatures of 0.5°C, 1.5°C and 3°C and left for five months to see if acidity levels reduced in over time. Fruit eating quality was tested at the following consortium meeting in March 2005.

RESULTS (OBJECTIVE 2, Sub objectives 2.13 – 2.19, FINAL REPORT)

2.13 Assess pests and diseases during establishment &
2.16 Assess pest and disease levels in June and at harvest

Table 2.2. Incidence of scab on variety trial orchard VF216 2002-2004

	16.9.2002	18.6.2003	15.7.2004	
Variety	**No. of leaves infected with scab**	**No. of leaves infected with scab**	**No. of trees showing symptoms of leaf scab**	**No. of trees showing symptoms of fruit scab**
Ariwa	0	0	0	0
Bohemia	0	0	1	1
Ceeval	0	0	0	4
D3	0	0	0	0
Delorina	0	0	0	0
Discovery	0	0	0	1
DL11	0	0	0	0
Ecolette	0	0	1	1
Edward VII	0	0	0	0
Encore	0	0	2	4
Florina	0	0	0	0
Goldrush	0	0	0	0
Howgate W.	0	0	0	0
Judeline	0	0	0	1
Liberty	0	0	0	0
Pikant	0	0	0	0
Pilot	0	0	13	7
Pinova	9	0	15	17
Rajka	0	0	0	0
Rebella	0	0	0	0
Red Falstaff	0	0	6	2
Red Falstaff. (g)	0	0	1	3
Resi	0	0	0	0
Rubinola	0	0	0	0
Rubinstep	0	0	4	0
Santana	0	0	2	1
Topaz	0	0	0	0
Worcester P.	0	0	1	3

Scab on VF216: 2002-2004

The results from assessment of levels of scab on VF216 are presented in Table 2.2 above. Pinova was the only variety to show any symptoms of leaf scab in 2002, although it was not an ideal time to assess the disease. During 2003, no scab was found on any variety due to the very dry weather. Despite the wet spring, incidence of scab on both leaves and fruit was also low on most varieties in 2004. *(In 2004, records of scab incidence were recorded slightly differently to 2002/ 03 in that the number of trees showing symptoms of leaf and fruit scab were noted (18 trees of each variety were assessed in total, rather than assessments of 10 leaves per tree for symptoms).* The highest incidence of scab in 2004 occurred on Pilot and Pinova (neither variety is scab resistant) with small amounts of both leaf and fruit scab on Bohemia, Ecolette and Encore (all reputed scab resistance), Red Falstaff and Worcester

Pearmain (no resistance) and Santana (reputed scab resistance). Low levels of leaf scab were also found on Rubinstep (reputed scab resistance) and low levels of fruit scab were found on Ceeval, Discovery and Judeline. Incidence of scab was so low in most years that statistical analysis was not possible, although by 2004 it appeared that the fungus was beginning to establish on several varieties in the orchard.

Table 2.3. Incidence of secondary mildew on VF216 (all blocks) 2002-2004

	16.9.2002	**18.6.2003**	**15.7.2004**
Variety	**Total severity of secondary mildew**	**Total number of mildewed leaves**	**Total number of mildewed leaves**
Ariwa	15	50	50
Bohemia	24	61	33
Ceeval	36	16	12
D3	19	24	7
Delorina	29	48	74
Discovery	6	5	7
DL11	32	70	70
Ecolette	8	27	24
Edward VII	19	13	5
Encore	3	28	10
Florina	23	32	17
Goldrush	47	95	120
Howgate W.	16	7	8
Judeline	18	44	42
Liberty	29	69	58
Pikant	23	19	31
Pilot	45	34	46
Pinova	39	65	33
Rajka	0	14	3
Rebella	13	11	7
Red Falstaff	59	57	22
Red Falstaff. (g)	*	20	34
Resi	26	58	43
Rubinola	12	34	11
Rubinstep	26	35	16
Santana	18	34	39
Topaz	12	16	12
Worcester P.	20	29	7

Mildew on VF216: 2002-2004

Table 2.3, above, shows the incidence of mildew on VF216 between 2002-2004. During 2002, the trees were very young and just becoming established with little vegetative growth. Therefore, as with the assessment of scab, one shoot per tree was examined for symptoms of late season (secondary) mildew and scored for severity (0=none, 4=severe). During 2003 and 2004, the assessments were conducted slightly differently and the total number of leaves showing symptoms of secondary mildew (out of a total of 180 leaves assessed) were recorded.

Secondary (late season) mildew was apparent on all cultivars except Rajka during 2002. Incidence of mildew appeared to be far more pronounced on the variety Red Falstaff than any other cultivar. The varieties Goldrush, Pilot, Pinova, Ceeval, Delorina and DL11 also had comparatively high levels. During 2003, the most severely affected cultivar was Goldrush with a total of 95 leaves showing symptoms of mildew. The varieties DL11, Liberty, Bohemia and Pinova also had high levels of infection (more than one third of leaves examined had symptoms of mildew). Once again, in 2004, Goldrush had the highest incidence of mildew with 120 out of 180 leaves showing symptoms of mildew. The varieties Delorina, DL11 and Liberty also continued to show relatively high levels of susceptibility.

Effects of sulphur on treated blocks

Sulphur was applied to blocks I, IV and V during years 2002-2004. Blocks II, III and VI were untreated. Applications of sulphur appeared to have been successful in reducing the incidence of mildew on most varieties but differences in the incidence of mildew between cultivars did not prove to be significant statistically.

Table 2.4. Incidence of rosy apple aphid on VF216

Number of colonies per variety

Variety	16.9.2002	18.6.2003	15.7.2004
Ariwa	0	6	2
Bohemia	1	3	2
Ceeval	9	4	5
D3	9	5	2
Delorina	0	0	0
Discovery	1	6	4
DL11	0	2	3
Ecolette	2	8	3
Edward VII	0	1	2
Encore	0	0	1
Florina	1	4	6
Goldrush	1	0	0
Howgate W.	0	9	5
Judeline*	0	1	2
Liberty	0	0	0
Pikant	0	4	2
Pilot	17	5	9
Pinova	4	3	7
Rajka	3	5	2
Rebella	1	6	7
Red Falstaff	0	8	6
Red Falstaff. (g)	*	0	0
Resi	0	3	1
Rubinola	0	1	0
Rubinstep	0	10	9
Santana	0	2	1
Topaz	0	3	4
Worcester P.	0	5	3

Pests on VF216: 2002-2004

During establishment of the variety trial orchard and over the subsequent two years, pest levels within the orchard remained low and erratic. Rosy apple aphid was the main pest noted during assessments where the number of trees showing infestation with rosy apple aphid were recorded each year (out of a total of 18 trees assessed – see Table 2.4, above). Varieties differed in their susceptibility to the pest, although Pilot, Rubinstep and Pinova appeared to have higher levels of infestation in most years, compared to other varieties. The varieties Liberty and Delorina were the only varieties to remain completely free of the aphid in 2002-2004.

2.17 Assess agronomic performance

Shoot growth measurements were carried out on VF216 during the dormant period in winter 2002, 2003 and 2004. It should be noted that some trees were grafted during 2001, whilst some varieties were grafted during 2002. Further losses and weak-growing cultivars were re-grafted during 2003, therefore many trees were at different stages of development.

Table 2.5. Shoot growth on VF216: 2002-2004

Variety	Total (mean) shoot growth		
	2002	**2003**	**2004**
1) Ariwa *	28.9	16.94	15.1
2) Bohemia	20.9	16.39	17.95
3) Ceeval *	17.0	11.14	8.9
4) D3	16.2	13.78	11.1
5) Delorina	26.9	19.64	12.76
6) Discovery*	15.3	11.93	9.6
7) DL11	22.9	15.89	11.15
8) Ecolette	17.8	15.13	11
9) Ed VII *	18.8	10.7	9.4
10) Encore	22.7	14.25	8.05
11) Florina	24.2	17.59	15
12) Goldrush	21.3	13.35	11.31
13) Howgate *	17.1	18.49	17.4
14) Judeline*	27.6	17.0	14.0
15) Liberty*	17.8	16.89	14.75
16) Pikant	15.5	11.86	9.45
17) Pilot	16.3	12.99	13.05
18) Pinova	21.0	15.18	12.4
19) Rajka	17.2	8.25	4.4
20) Rebella	14.3	13.47	11.64
21) Rd Fff	8.6	13.35	9.03
22) R.Fff.g *	21.5	17.92	12.55
23) Resi	17	13.26	9.55
24) Rubinola	17.8	10.57	8.7
25) Rubinstep	16.5	17.04	16.7
26) Santana	17.7	17.21	15.1
27) Topaz	19.5	14.86	12.8
28) Worcester.P	24.1	18.2	16.83

** = grafted 2001*

Shoot growth 2002-2004

It can be seen from the results in Table 2.5. that the most vigorous varieties in terms of shoot growth during 2002 were Ariwa, Judeline, Delorina, Florina and Worcester Pearmain, with the latter three also making good growth during 2003. These varieties also appear to have a good spreading habit and have established a good branch framework early on. With the exception of Worcester Pearmain, which is partially tip-bearing, all varieties assessed appear to be spur bearing in habit. Despite being grafted one year later than other varieties, Judeline and Red Falstaff (g) appeared to make very good growth.

Measurements of shoot growth taken during winter 2004-2005 show that the varieties Bohemia, Howgate Wonder, Worcester Pearmain, Rubinstep and Ariwa were the most productive in terms of new shoot growth during 2004, with a total mean shoot growth of over 15dm per 6 trees. These varieties also made good growth in 2003 with a total mean shoot growth of over 16dm per 6 trees. The variety Rajka made the poorest growth during 2004 (and also during 2003) but this may have been due to poor quality graftwood. Overall, the varieties Judeline and Worcester Pearmain were the most consistent in their vigour in terms of production of new extension growth in 2002-2004.

Table 2.6. Notes on tree form and habit 2003-2004 and fruit observations 2004.

	Tree form and habit	**Fruit notes**
Variety	**2003 / 2004**	**2004**
1) Ariwa	Vigorous, upright spreading. Very good extension growth. Well branched.	Fruit can be difficult to pick. Fruit thinned in late June.
2) Bohemia	Weak – moderate vigour. Upright habit.	Very highly coloured.
3) Ceeval	Upright – slightly spreading Rather weak. Moderate extension growth.	Fruit thinned in late June.
4) D3	Upright spreading – sturdy Moderate vigour.	Very deep purple/red. Prominent lenticels.
5) Delorina	Upright – spreading. Very vigorous. Good extension growth – well branched.	Poor colour.
6) Discovery	Moderately vigorous, upright spreading. Good growth.	Bird damage.
7) DL11	Upright, slightly spreading.	Poor fruit size/shape.
8) Ecolette	Vigorous, spreading, well branched	Small, tendency to overcrop.
9) Ed VII	Moderately vigorous, upright spreading. Bare scaffolds. Sturdy.	Bitter pit on some fruits.
10) Encore	Upright, compact, narrow branch angles Weak. Some long extension growth.	Very large fruits.
11) Florina	Vigorous, upright spreading. Good form	Poor colour.
12) Goldrush	Moderate vigour, spreading, well branched	Prone to sooty blotch.
13) Howgate	Upright, compact and sturdy Moderately vigorous. Long extension	Very large fruits.

	growth. Large leaves.	
14) Judeline	Upright spreading, good growth Long extension growth.	Fruits thinned in late June.
15) Liberty	Moderately vigorous, spreading. Good, open form. Branches few but well spaced.	Short stalks.
16) Pikant	Upright – weakly spreading Little new growth. Small leaves.	Erratic ripening.
17) Pilot	Spreading, well branched Moderate vigour.	Similar to Cox.
18) Pinova	Vigorous, spreading habit. Good framework. Crippled by mildew.	Long stalks. Fruit thinned in late June.
19) Rajka	Upright, compact, narrow angles Weak-moderate vigour. Moderate growth.	Short stalks – earwigs. Fruit thinned in late June.
20) Rebella	Very vigorous, spreading habit. Good extension growth. Good framework.	Long stalks – similar to Resi. Fruit thinned in late June.
21) Rd Fff	Spreading, very well branched Moderately vigorous. Good growth. Large, long leaves.	Fruit thinned in late June.
22) R.Fff) (grafted 2002)	(only recently grafted) As above	-
23) Resi	Vigorous, upright spreading habit. Plenty of new extension growth. Good form, well branched.	Long stalks. Fruit can be hard to pick. Fruit thinned in late June.
24) Rubinola	Spreading, rather spindly growth. Weak vigour (canker?). Bare scaffolds, few branches.	Slight *Phoma* leaf spot on fruit.
25) Rubinstep	Vigorous, upright. Good form. Good new extension growth. Strong framework.	Good size and shape.
26) Santana	Weak-moderate vigour. Upright-spreading habit. Sturdy framework.	Very highly coloured.
27) Topaz	Weak-moderate vigour. Upright habit, compact.	Poorly coloured fruits.
28) Worcester.P	Moderately vigorous, upright – spreading. Good sturdy framework.	Bird damage.

Tree form, habit and fruiting

Preliminary observations on variety form and habit from 2002-2004 (Table 2.6) showed that most varieties were upright-spreading in habit, although vigour varied greatly between varieties. During the extremely hot weather of summer 2003, it was noted that the varieties Pinova, Rajka, Red Falstaff and Resi showed signs of drought stress, whilst other varieties appeared to be less affected. It was noted that varieties which produced fruits with exceptionally long stalks (Ariwa, Rebella and Resi) had a tendency to be difficult to pick, whilst those with very short stalks (Ceeval, Rajka) tended to encourage colonisation by

earwigs around the stalk end. The promising variety Rubinola continued to perform rather poorly (weak vigour, little growth, very light crop) although this may have been due to susceptibility to canker or poor quality grafting material. 8-year old trees of the variety growing on M9 rootstocks at nearby Rock's Farm have also shown a tendency for bare scaffold branches and sparse foliage development, but crop relatively heavily and reliably each year.

Pollination, floral precocity and crop load in 2003 & 2004

Preliminary records of fruiting precocity, taken during the summer of 2003 revealed that the varieties Ariwa, Red Falstaff, Pinova, Pilot, Rebella and Delorina appear to be the earliest to bear fruit. Hand-thinning was required for the varieties Ariwa, Delorina, Rebella and Resi. However, these were only preliminary observations since most of the varieties had only just started to bear fruit, having only recently become established.

Table 2.7. VF216: Flowering and crop load characteristics 2004

Variety	Bloom density	Flowering stage at 29th April 2004	Pollination group	Crop load 2004
1) Ariwa *	3	Pink bud	3	Heavy
2) Bohemia	2	20% bloom	3	Moderate
3) Ceeval *	4	70% bloom	2	Heavy
4) D3	1	60% bloom	2	Light-moderate
5) Delorina	3	Gc – Pb	4	Heavy
6) Discovery*	4	30% bloom	3	Moderate
7) DL11	3	30% bloom	3	Light
8) Ecolette	4	40% bloom	3	Heavy
9) Ed VII *	1	Green cluster	6	Heavy
10) Encore	1	Pink bud	3	Moderate
11) Florina	5	90% bloom	1	Moderate-heavy
12) Goldrush	2	20% bloom	3	Light
13) Howgate *	1	Pink bud	3	Heavy
14) Judeline*	5	20% bloom	3	Very heavy.
15) Liberty*	5	40% bloom	3	Heavy
16) Pikant	3	Pink bud	3	Light-moderate
17) Pilot	5	15% bloom	3	Heavy
18) Pinova*	5	15% bloom	3	Heavy
19) Rajka *	3	70% bloom	2	Light- moderate
20) Rebella	3	30% bloom	3	Very heavy
21) Rd Fff *	3	50% bloom	2	Heavy
22) R.Fff.g *	5	Pink bud	2	Light
23) Resi *	5	20% bloom	3	Heavy
24) Rubinola*	2	30% bloom	3	Very light
25) Rubinstep *	3	20% bloom	3	Light
26) Santana	3	45% bloom	2	Moderate
27) Topaz	3	50% bloom	2	Moderate
28) Worcester.P	4	Pink bud	3	Moderate

* = thinned during June.

Bloom density rating:
5 = very heavy, 4 = heavy, 3 = moderate, 2 = light, 1 = very light/none.
Pollination group:
1 = very early flowering, 6 = very late flowering.

Assessment of floral precocity and flowering stage were undertaken in spring 2004, and an assessment of crop load was made later that year during August (as shown in Table 2.7, above). Varieties which had shown a very heavy bloom density during April all set a heavy crop load and hand thinning was carried out in late June where fruit set was too heavy. Records of bloom density and flowering stage taken during April 2004 gave a good indication of the likely pollination group of each variety. The varieties Florina, Judeline, Liberty, Pilot, Pinova, Red Falstaff and Resi all had a very heavy bloom set during the spring. When the assessment was carried out on the 29th April, Florina was the most advanced variety with 90% bloom. Ceeval and Rajka were also relatively early flowering with 70% bloom. The least advanced variety in terms of flowering was Edward VII, (which is notoriously late flowering: pollination group 6), which was still at the green cluster stage. Delorina was also relatively late at the green cluster – pink bud stage. Most other varieties were between the pink bud and 50% bloom stage, indicating that they would be likely to fall into 'normal' pollination groups of 2 and 3.

2.18 Conduct taste and processing tests

Evaluations in 2002 & 2003

Staff from Sainsbury's and Waitrose fruit technology departments continued to evaluate promising apple varieties for organic production using a sensory evaluation sheet (as described in materials and methods, section 2.4) during 2002 and 2003, with a view to selecting a final short-list of 10 varieties for large scale evaluation during 2004. In many cases, opinions on the acceptability of each variety varied widely, and it was difficult to reach an overall conclusion on the performance of the fruit. Detailed results from the evaluations are given in the respective reports covering years 3-4 of the project. Table 2.8 summarising the overall outcome (overall rating) for each fruit variety during 2002 and 2003 is shown below:

Table 2.8. Summary of acceptability ratings for promising apple varieties 2002-2003

Variety	Overall rating in 2002	Overall rating in 2003	Outcome
Ariwa	*	Good	Short-listed
Bohemia	Pleasant	Indifferent	Rejected
Ceeval	Fair	Good	Short-listed
D3	*	Poor	Rejected
Delorina	Fair	Pleasant	Short-listed
DL11	*	Fair	Rejected
Ecolette	Indifferent	*	Rejected
Florina	Fair	Fair	Rejected
Goldrush	*	Indifferent	Rejected
Liberty	Pleasant	Pleasant	Short-listed
Pilot	Poor	*	Rejected
Pinova	Good	Fair	Short-listed
Rajka	Fair	Pleasant	Short-listed
Rebella	*	Fair	Rejected

Red Falstaff	Indifferent	Pleasant	Rejected
Resi	*	Good	Short-listed
Rubinola	Pleasant	Good	Short-listed
Rubinstep	*	Good	Short-listed
Santana	*	Fair	Rejected
Topaz	Very bad	*	Rejected
Worcester Pearm.	Pleasant	Fair	Rejected

**** Fruit not evaluated***

Pinova was the highest rating variety in 2002 with very good eating quality although yellow background colour was an issue and there was concern about the variety's lack of disease resistance. It performed less well the following year in 2003, receiving only an average rating. Varieties Rubinola, Liberty and Bohemia achieved overall ratings of 'pleasant' in 2002. Despite also achieving a good rating in 2003, there were concerns with fruit greasiness and cracking round the stalk end of Rubinola fruits – a trait that was noted during previous assessments. Blemishes on the skin of Rubinola due to leaf spot were also a problem in 2002. Despite concerns about density of the flesh, preliminary observations on storage quality showed that the variety can store very well and it was short-listed for evaluation in 2004.

The varieties Liberty and Bohemia evaluated reasonably well in 2002, although there were mixed opinions on eating quality. Bohemia, in particular was noted for its good flavour, but slightly greasy skin and oversized fruit were an issue. Subsequently, it was found to be of 'indifferent' quality in 2003 and was therefore rejected. Opinions on Liberty suggested that fruit colour may be too dark and mixed fruit maturity may be a problem, although it was short-listed for large scale taste-test evaluation in 2004.

The varieties Rajka, Florina and Delorina received an overall rating of 'fair - pleasant' during 2002 and 2003. There were mixed opinions on the taste and quality of Rajka, but cracking around the stalk end did not appear to be a problem in 2002 (unlike previous years). The variety proved to have a limited storage life in air. The variety Ceeval proved difficult to harvest during 2002 due to notable problems with mixed fruit maturity. Two picks were necessary to try to improve fruit colour and quality and there was great variation in fruit size and shape. At best, fruits are well sized, conical, orange blushed with crisp, fresh eating quality. This variety also has a short shelf-life and susceptibility to mildew may result in fruit russetting, a problem which has also been noted in previous years. During 2003, attempts were therefore made to fine-tune the picking date with the resulting improved rating of 'good.' Delorina and Florina were found to have fairly good eating quality overall, although Florina was found to have poor colour and skin finish, resulting in it being rejected by the panel at the end of 2003. The shape and skin finish (greasiness) of Delorina was also questionable, although it remained short-listed for further evaluation in 2004.

The varieties Ecolette and Red Falstaff were rated 'indifferent' by the panel in 2002. Ecolette was found to be very acidic with a tough, waxy skin – a trait that did not appear to improve during storage. Cracking was also a problem around the stalk end of fruits and it was rejected at the end of 2002. Red Falstaff evaluated relatively poorly compared to previous years in 2002 but this may have been due to the fruits being slightly over-mature and it subsequently achieved a better rating the following year. However, due to its lack of disease resistance (susceptibility to mildew) the decision was taken at the end of 2003 to eliminate it from the short-list.

The varieties Topaz and Pilot, despite having performed reasonably well in previous assessments, did not live up to expectation in 2002. Fruits of Topaz were sourced from two different sites (Rock's Farm, East Malling and North Court fruit farm, Chilham) during 2002 but samples received poor ratings for appearance, despite being well coloured (blotchy red stripes over orange flush). Greasiness was also a problem and high fruit acidity was not to everyone's taste. The panel also generally disliked Pilot, which performed exceptionally well in storage trials and had evaluated reasonably well in previous years. The decision was taken to eliminate both varieties from the short-list although subsequent storage tests were performed on Topaz in 2004 to see if acidity levels decreased in storage.

At the end of 2003, a variety review meeting was held to review each variety in detail, with previous year's assessments also taken into consideration. This resulted in a short-list of 10 varieties being drawn up for final, large scale evaluation at the Sainsbury's Centre in 2004.

Culinary varieties

There was not enough room to include culinary varieties for taste panel assessment at the Sainsbury's centre in 2002, but samples were included in preliminary storage trials (see results section 2.19). Having previously been assessed for processing by Fourayes Farms Ltd, the four short-listed culinary varieties (most suitable for processing), were assessed by the supermarket evaluation panel for fresh sales during the variety review meeting in 2003. It was agreed that all four varieties (Edward VII, Encore, Howgate Wonder and Pikant) would be suitable, providing there was not too much top colour present on the skin.

Juicing variety

The variety Judeline was scheduled to be assessed for juicing potential, using the juice press at Oakwood farm during 2002. Unfortunately, having cropped very well for several years, yields of Judeline from Poultry Farm were very low in 2002 and there were not enough fruits for juicing and juice trials were postponed until 2003. It was hoped that the trees (cropping at Poultry Farm, Marden) would have produced enough fruit to supply the commercial juice press at Matthew Wilson's farm. However, although the trees cropped well during 2003, they failed to produce sufficient volume of fruit to supply the half-tonne requirement of the press. Although the apples were put through a domestic 12l press, it would have been interesting to note how the variety performed in a commercial situation. Attempts were made to source ready-bottled juice from France, but it was impossible to find a single blend of plain juice. However, after further assessments of storage quality, the variety was found to have extremely poor storage life in both air and CA (see results section 2.19) and it was agreed by the panel not to pursue the variety any further. It is likely that if a juicing apple is to be recommended to growers, the established juicing varieties Fiesta or Red Falstaff will be perfectly adequate for organic juice production.

Final large-scale evaluations during 2004

Sainsbury's Product Testing Questionnaire

The results from the Sainsbury's product testing questionnaire are summarised in Tables 2.9 and 2.10 below: Table 2.9 shows the attribute ratings (score out of 10 where 0 = poor and 10 = excellent) for visual appeal (appearance, shape and colour) and eating quality (flavour and texture). An overall average score is also given for each variety. Table 2.10 shows the percentage of consumer preference when asked 'would you buy this product?' A positive

'yes' total is the percentage combination of 'yes, definitely' and 'yes, probably' responses. The negative total is the percentage combination of 'no' and 'don't know' responses.

Table 2.9. Attribute ratings (score out of 10).

Test	Variety	Appearance	Shape	Colour	Flavour	Texture	Overall score
1	Discovery	7.44	7.45	7.38	6.25	5.58	6.19
1	Ceeval	6.76	7.53	7.16	6.73	7.15	6.90 *
2	Rajka	7.18	7.57	7.46	7.08	7.33	7.14 *
2	Resi	7.46	7.55	7.59	6.73	7.18	6.93
3	Rubinola	7.18	7.51	7.74	7.64	7.58	7.54 *
3	Red Fstff	7.24	7.63	7.48	6.12	6.72	6.50
4	Ariwa	7.03	7.24	7.20	6.22	6.55	6.59
4	Pinova	7.06	7.52	7.10	7.17	7.10	7.26 *
5	Rubinstep	7.72	7.42	7.76	7.66	7.64	7.50 *
6	Liberty	6.71	7.25	7.08	6.41	5.79	6.42
6	Delorina	7.41	7.40	7.57	6.94	6.57	6.97 *

+ represents significant difference in preference between the two varieties tested at the 80% confidence level.

Table 2.10. Consumer preference: Would you buy this product? (percentage terms)

Variety	Yes, definitely	Yes, probably	Positive 'yes' total	No	Don't know	Negative total
Discovery	12	26	38	45	16	61
Ceeval	23	32	55	34	12	46
Rajka	23	36	59	32	9	41
Resi	17	38	55	31	14	45
Rubinola	28	45	73	17	10	27
Red Fstff	11	34	45	47	9	56
Ariwa	17	33	50	41	8	49
Pinova	17	53	70	20	10	30
Rubinstep	21	55	76	17	7	24
Liberty	12	34	46	45	9	54
Delorina	16	41	57	28	15	43

The results from the Sainsbury's product testing evaluations show that out of the eleven dessert varieties evaluated, the varieties Rubinola, Rubinstep, Pinova and Rajka achieved the highest overall scores respectively for attribute ratings (appearance, shape, colour, flavour and texture) with scores above 7/10 for each parameter assessed. Delorina, Resi and Ceeval also achieved relatively high overall scores between 6.9 and 7.0.

In most cases, two varieties were compared during each test (e.g. Discovery vs Ceeval in test 1, Rajka vs Resi in test 2 etc.) and in all cases there was a statistically significant difference in preference between the varieties at the 80% confidence level. Unfortunately, only a very limited number of Rubinstep fruits were available for harvest from trees on VF216, and although additional fruits were requested from the Czech Republic, insufficient numbers were sent to make up a sample of 100 fruits. In total, 50 fruits were sent for evaluation at Sainsbury's and it was necessary to halve the fruits in order to supply enough of the product to give to 100 panellists. Rubinstep was also evaluated in a single test without comparison with an accompanying variety, although the eventual scores achieved by the variety were compared to a mean of all previous varieties tested to give an indication of its performance.

As an important component of the questionnaire, consumers were asked whether they would buy the organic apples after sampling each variety. Table 2.10 shows the percentage breakdown of positive responses and it can be clearly seen that of all the varieties tested, Rubinstep was the most popular with 76% of consumers responding positively, with either a 'definite' or 'probable' purchase. Rubinola and Pinova were also popular with a 73% and 70% positive response respectively. The least favoured varieties were Discovery (61% negative response), Red Falstaff (56% negative response) and Liberty (54% negative response) where more than half of the consumers involved in the questionnaire stated that they would either not buy it, or didn't know. (A 'don't know' response could also be viewed favourably, but it was assumed here that if the variety had not achieved a good initial reaction from the consumer, it would be unlikely to be purchased when placed alongside other popular commodity varieties and competing for shelf space (no 'point of difference') and repeat-purchase would also be unlikely).

Variety evaluation results from Waitrose

Small samples (10-15 fruits) were sent to Waitrose for evaluation during August – October 2004. Unfortunately, apples from some of the varieties were damaged in transit and of the varieties sent, not all could be evaluated due to time constraints. However, six varieties were evaluated in total by a small panel of fruit technologists. As mentioned in the materials and methods section of this report, the evaluations were completed using a standard sensory profiling sheet. Of the varieties evaluated, Ariwa and Pinova scored highest for firmness (scores above 7/10) with Ariwa also achieving the highest average score for crispness. Pinova was found to be tough with a high score of 8/10. Rubinstep was the sweetest variety with a score of 7.5/10. However, there was very little difference generally between most varieties and an average overall rating of 'pleasant' was awarded to the varieties Red Falstaff, Ariwa, Pinova and Rubinstep. Rubinola and Liberty achieved ratings of 'indifferent.'

GENERAL DISCUSSION ON RESULTS OF VARIETY EVALUATIONS

Whilst the large-scale consumer product testing questionnaire conducted at Sainsbury's and the smaller scale sensory fruit evaluations at Waitrose provided some quite conclusive results in terms of consumer preference, a number of factors need to be taken into consideration when reviewing the overall performance of the varieties.

Owing to the need to supply two varieties at a time for product testing at Sainsbury's, it was necessary to hold the variety Discovery in cold storage (at 1.5-2°C) for two weeks before evaluation, so that it could be supplied alongside the second-early season variety Ceeval for comparison testing. This delay undoubtedly had an adverse effect on the variety's

performance in the evaluations as fruit quality was past its best. Although not ideal, this result confirms the difficulty in supplying this variety (as a supermarket variety) at its best as its season is extremely short. Although the variety performs well in organic trials due to its disease resistance, it is only likely to be recommended for farm shop sales, and not as a mainstream organic variety marketed through the multiples.

Due to the nature of producing the varieties under organic protocols (where fruit supplied for supermarket evaluation was harvested exclusively from the young organic trial on VF216), fruit quality of several varieties, namely Rajka and Rubinola was quite poor, due to caterpillar (tortrix) damage and Phoma leaf spot on fruits respectively. If these varieties had been produced under conventional regimes, or even sourced from older, established organic trees, the visual quality of fruits at harvest would undoubtedly have been better. Also, although hand-thinning of heavy cropping varieties was carried out in June, many fruits of the variety Resi were undersized, indicating that earlier, harder thinning is necessary with this variety to achieve good fruit size.

Despite several factors limiting fruit quality and visual appeal, the combined results from Sainsbury's and Waitrose consumer taste-tests have shown that it is possible to produce organic apples to acceptable consumer standards and it is highly encouraging that a clear preference for specific varieties has been demonstrated.

2.19 Conduct preliminary storage tests

Air storage trial in 2002

During 2002, basic air storage tests were conducted on most varieties (where sufficient fruit was available). The results are presented in Table 2.11. There were no obvious adverse reactions to low temperatures and signs of breakdown in any variety. Some varieties held their firmness in storage far better than others and not surprisingly, fruits in the coldest store (0-0.5°C) remained in the best condition throughout. Table shows the average firmness of each variety after removal from the three different store temperatures (0-0.5°C, 1.5-2°C and 3°C) during mid-November, mid-December and end-January.

The best storing varieties in air until January were Pilot and Liberty. Pilot held its firmness exceptionally well in all temperature regimes for the duration of the trial. Ecolette, Pinova, Delorina and the culinary variety Pikant also kept in relatively good condition until January at 0-0.5°C with firmness remaining above 60 Newtons. Varieties Topaz and Santana and the culinary varieties Encore and Howgate Wonder kept relatively well until December at 0-0.5°C. The varieties Rajka, Florina and Red Falstaff performed relatively poorly in air storage.

Table 2.11: Fruit firmness (Newtons) after storage at three different air temperatures

Variety	November removal Maximum load (N)			December removal Maximum load (N)			January removal Maximum load (N)		
	0-0.5°C	1.5-2°C	3°C	0-0.5°C	1.5-2°C	3°C	0-0.5°C	1.5-2°C	3°C
Pinova	70.78	67.65	69.66	71.19	64.10	63.59	67.30	52.95	51.65
Pilot	86.10	82.93	83.24	84.15	81.54	86.58	85.05	85.48	83.26
Ecolette	93.06	84.58	77.34	73.65	68.30	64.75	73.89	55.90	48.26
Topaz	89.14	89.66	77.31	73.94	63.45	59.56	55.12	55.62	46.41
Rajka	62.37	55.71	47.38	47.08	41.22	42.43	42.11	43.53	37.12
Santana	66.68	62.29	63.54	54.42	52.56	50.96	46.62	47.45	42.70
Florina	69.19	61.01	45.48	56.43	38.86	35.06	43.24	33.16	32.45
Delorina	92.53	84.11	81.25	74.61	65.34	60.49	62.61	59.10	55.80
Red Falstaff	60.74	58.15	52.15	49.22	41.99	39.54	40.58	36.78	33.84
Liberty	84.81	71.71	68.06	77.93	68.84	65.72	60.25	59.76	59.77
Encore	75.40	68.13	66.95	66.78	49.60	47.96	51.05	43.36	42.67
Howgate W.	63.58	63.91	61.64	58.93	52.18	45.98	52.70	41.35	36.35
Pikant	72.883	70.72	67.25	64.91	56.76	53.36	62.22	49.75	47.81
Bohemia		53.98			43.33			38.63	

Controlled Atmosphere storage trial in 2003

Following the basic air storage trial of 2002, a preliminary trial in CA storage was conducted on most of the promising varieties in 2003. Samples of fruit from each variety were sorted into batches and stored in CA conditions at a temperature of 2ºC, with batches being removed for assessment at 2, 4 and 6 months after harvest. The results are presented in Table 2.12, below.

Table 2.12. Mean fruit firmness (Newtons) of CA-stored organic apple varieties

Variety	Firmness (N) at harvest	Firmness (N) 2 Months	Firmness (N) 4 Months	Firmness (N) 6 Months
Ariwa	93.7	90.6	76.6	61.5
Bohemia	64.2	45.6	42.4	*
Ceeval	70.7	45.4	27.4	*
DL11	64.0	54.9	54.6	52.1
Edward VII	88.5	86.8	69.2	47.2
Encore	73.7	69.0	50.4	42.1
Florina	77.5	57.6	42.5	42.8
Goldrush	92.2	92.2 (fresh)	97.4	89.8
Judeline	86.0	68.2	52.0	47.3
Liberty	79.0	80.0	58.2	53.7
Pikant	88.6	78.1	67.1	44.3
Pilot	93.3	92.1	88.1	82.8
Pinova	71.6	73.8	70.8	71.3
Rajka	83.2	71.3	60.9	49.4
Rebella	79.4	78.7	67.0	*
Red Falstaff	69.5	68.2	59.7	56.2
Resi	90.0	86.8	70.9	*
Rubinola (early pick)	87.7	77.5	68.0	52.9
Rubinola (late pick)	86.1	83.7	62.0	51.9
Rubinstep	94.4	85.7	74.5	*
Santana	72.5	80.9	81.7	*
Topaz	82.3	75.0	65.3	53.7

***** = no fruit available

After 6 months in CA storage, clear trends in cultivar performance were evident. The variety Pilot, which performed exceptionally well in air storage trials during 2002, also retained its firmness very well in CA (average firmness dropping by 93.3 – 82.8N over 6 months). The variety Santana (not previously evaluated in storage trials owing to lack of fruit) also appeared to perform well in CA, and maintained a firmness of around 80N over a four month period, although a shortage of fruit meant that there were no fruits available for assessment after 6 months. The late maturing variety Goldrush (harvested in early November) also had an excellent storage life. Unfortunately, these varieties were eliminated from the short-list of promising varieties owing to poor eating quality.

Of the more promising short-listed dessert apple varieties to be selected by Sainsbury's and Waitrose in 2002-03, the varieties Ariwa and Pinova maintained a very good fruit firmness of above 60 N over the six month period. The varieties Rubinstep, Resi and Rubinola also appeared to perform relatively well in CA, maintaining an average firmness of over 60 N over a four month period, but did not hold their firmness for a full six months. Observations of appearance and quality of fruit removed from CA store confirmed that the variety Resi was prone to soft-scald at temperatures below 2°C. The closely-related variety Rebella was also affected in this way. This kind of physiological disorder can usually be overcome by modifying the temperature at which the fruits are stored.

The promising dessert varieties Red Falstaff, Rajka and Liberty (which had performed well in air storage trials during 2002-2003) maintained an average firmness at or just under 60 N in storage – indicating that these varieties may not be suitable for long-term storage. However, none of these other varieties showed any negative reaction to the CA regime and it should be possible to extend storage life by reducing the temperature to 0-0.5ºC and /or by applying a more extreme CA treatment. The variety Ceeval performed particularly poorly, but since this is an early apple (season similar to Worcester Pearmain) it was not expected to last well. Of the culinary varieties tested, Edward VII and Pikant proved to be the best keepers, maintaining a firmness of just under 70 N over four months. The juicing variety Judeline did not hold its firmness well in CA (dropping from 86 – 47.3 N over six months) and was not deemed suitable for long-term storage. There was not enough fruit of the varieties Delorina and Howgate Wonder to carry out assessments. The variety D3, which had been sourced from Poland, was not stored owing to extremely poor fruit quality (bruising).

Although the storage trials have given a good indications of typical responses of each variety held in air and CA regimes, it should be noted that these were only preliminary trials and further, more detailed storage work will be required for any varieties selected for final recommendation to growers. In many cases, there was little fruit available for storage work (the best apples having been sent for taste test assessment). Having been sourced largely from unsprayed plots, much of the fruit also had skin blemishes which may also have affected storage performance.

2.20 Collate and evaluate data

A full summary of results from pest, disease, agronomic assessments and the apple variety evaluations from years 2000-2004 have been discussed in this report (July 2005). However, of the most promising varieties selected for consumer acceptance testing in 2004, a brief summary of merits and concerns for each variety is shown in the Tables 2.13 and 2.14 below. The varieties are ranked in order of consumer preference.

Table 2.13. Merits and concerns of promising dessert apple varieties.

Rank	Variety	Advantages	Disadvantages	Pest and disease
1	Rubinstep (M-L)	Reputed excellent storage life in ULO. Performs well in evaluations.	(Mostly Czech fruit used for evaluation). Trees on VF216 are rather weak.	Prone to rosy apple aphid. Slight scab on VF216.
2	Rubinola (M)	Consistently high scoring in evaluations. Stores well (4 months in CA at 2°C). Reputedly vigorous in habit.	Cracking around stalk end. Can become greasy if over-mature. Trees on VF216 are weak.	Prone to leaf spot (Phoma) and canker.
3	Pinova (M-L)	Excellent eating and storage quality.	Requires thinning.	Not disease resistant. Prone to mildew.
4	Rajka (M)	Performs well in evaluations owing to good fruit flavour. 2-3 months CA storage life at 2°C.	Skin finish can be poor. Unsuitable for long-term storage.	Good disease resistance.
5	Delorina (L)	Trees are vigorous and productive.	Requires thinning. Fruits can become greasy. Colour variable.	Good disease resistance.
6	Resi (M)	Gala-like. Good eating quality. Trees are very vigorous and productive.	Requires hard thinning. Storage issues (susc to soft scald below 2°C in CA).	Good disease resistance. Slight mildew on VF216.
7	Ceeval (E-M)	Good alternative to Worcester Pearmain.	Mixed fruit maturity – requires several pick-overs.	Prone to mildew.
8	Ariwa (M)	Trees are vigorous and productive. Excellent storage life.	Variable fruit size and shape. Fruits can be greasy.	Good disease resistance. Mildew on VF216.

9	Red Falstaff (M)	Average flavour. Trees are vigorous and productive.	Can become greasy if over-mature. Unsuitable for long-term storage.	No disease resistance. Slight scab on VF216.
10	Liberty (L)	Unusual colour (Spartan-like).	Mixed fruit maturity. Requires thinning. Unsuitable for long-term storage.	Good disease resistance. Mildew on VF216.
11	Discovery (E)	Earliest promising organic apple.	Short shelf life.	Good disease resistance. Mildew on VF216.

Cropping season: E = early, M = mid, L = late

Table 2.14. Merits and concerns of promising culinary and juicing varieties:

Variety	Advantages	Disadvantages
Edward VII	Good disease resistance. Excellent fruit quality.	Can be slow to bear fruit and difficult to crop. Storage issues (scald). Bitter pit prone?
Encore	Very similar to Edward VII. Possibly better storage quality.	Very slight scab on VF216.
Howgate Wonder	Resistant to mildew. Good grower.	Too much top colour for fresh sales? Limited storage life (becomes greasy).
Pikant	Produces consistent crops of large, good quality fruit. 4 months CA storage life at 2°C.	Too much top colour for fresh sales? Not disease resistant.
Judeline (juicing)	Very vigorous, productive trees which are extremely disease resistant.	Questionable fruit quality. Short shelf life. Tendency to over-crop.

2.21 Identify best varieties

Following the variety evaluations by Sainsbury's and Waitrose in 2004, a meeting was held at the Sainsbury's Centre in December 2004 to discuss the results of the product testing evaluations and review the varieties in detail, with a view to selecting the best 4-6 for recommendation to organic growers. The meeting was attended by representatives from Sainsbury's and Waitrose and consortium members. It was agreed that of the final eleven varieties evaluated during the year, the varieties Ceeval, Rajka, Resi, Rubinola and Rubinstep would be recommended to growers. This selection ensured that at least one variety (Ceeval) fulfilled the early season market. The other four varieties are all main-season, but both Rubinola and Rubinstep have excellent storage potential (indicating that they could supply the post-Christmas market if required). Although the variety Pinova had performed consistently well in taste tests over successive years, it was agreed that the variety would not be

recommended due to its lack of disease resistance. It was also agreed that the early season variety Discovery would be recommended for non-supermarket sales only and that the late-season variety Delorina would not be recommended, but would, however, be retained for further evaluation, along with the popular European organic variety Topaz. All other varieties were considered to be of insufficient quality for supermarket sales.

Culinary and juicing varieties
Although no further evaluations of culinary or juicing varieties were undertaken in 2004, previous evaluations have shown that four culinary varieties (Edward VII, Encore, Howgate Wonder and Pikant) would be suitable for processing and also for fresh market sales, provided not too much top colour was present. It is still too early to tell if these varieties are any good for commercial organic growing, and ideally their agronomic performance needs to be evaluated on a larger scale, before they can be recommended to potential growers as a replacement for Bramley. The French juicing variety Judeline has shown promise as a highly productive and disease resistant variety, but its main drawback is lack of shelf-life, which may be of concern to commercial juice producers who are unable to process the variety straight after harvest. It could, however, be used as a pollinator where small-scale juice production is desirable.

A database of the short-listed varieties (dessert and culinary) which contains agronomic information and data from taste-test evaluations, collated throughout the life of the project (2000-2004) can be found in Appendix 4.

CONCLUSIONS (OBJECTIVE 2, FINAL REPORT)

Years 1&2

Criteria for selection of apple varieties for organic production
In order to be acceptable to the major multiple retailers in the UK, for volume sales, new or traditional varieties suitable for organic production must have a combination of attributes. At the outset of this project, the consortium agreed that in addition to resistance/tolerance to the principle diseases scab and mildew, varieties selected should ideally be attractive in appearance, of good size (>60mm) and of good eating quality (e.g. firm, juicy and have good texture, sugar/acid balance and flavour).

Apple variety database
A database containing information on more than 150 apple varieties with suitability for organic production was put together during the first year of the project. This database was used to store relevant information for each variety evaluated and also provided background information for decision making concerning the final selection / elimination of the most promising cultivars.

Preliminary screening of varieties
During the first year of the project (2000), the evaluation panel, comprising the marketing and retailing members of the consortium conducted taste and appearance evaluations on more than 100 dessert varieties and 35 culinary varieties. Although the condition of the samples evaluated by the panel was generally adequate, it was

recognised that some samples received from sources abroad were below standard. Repeat evaluations were carried out on approximately 42 apple varieties (including 6 culinary types) during the following year (2001). Culinary varieties were assessed using processing (pie-making) tests at Fourayes Farms to review flavour and consistency after cooking. Dessert types were evaluated on the basis of their internal eating quality and appearance. A meeting was held at the end of 2001 to review the evaluations and to decide on the choice of varieties to be included in a replicated variety trial, planted at East Malling. Using the results of the taste evaluations together with a database of information gleaned from other trials and observations in the UK and abroad, 1 juicing, 22 dessert and 4 culinary varieties showing promise for organic culture were selected for further, more detailed evaluations over the next 3 years of the project.

Year 3

Establishment of organic variety trial planting
Having acquired budwood of the 27 promising varieties selected for further evaluation, and grafting onto 2 year old ex-Saturn trees on M9 rootstocks, a replicated experimental orchard was planted on Village Field site (VF216) at East Malling Research during the winter of 2001. The orchard established well during 2002, although some trees needed re-grafting to compensate for those lost to canker or those which had generally made poor growth.

Treatments and assessments during establishment
Sulphur was applied to three blocks on VF216 on ten separate dates from April - August during 2002 and appeared to successfully reduce the incidence of mildew on most varieties. The planting was assessed for secondary mildew, leaf scab, rosy apple aphid and canker during September. Although pest and disease incidence was generally low due to the juvenility of the orchard, all cultivars except Rajka showed symptoms of mildew, with Goldrush being the worst affected. Incidences of scab, rosy apple aphid and canker were apparent on some cultivars, but generally at low levels.

Continued evaluation of promising apple varieties
Samples of fruits (UK-grown varieties only) were supplied to the Sainsbury's Centre on four separate dates during September and October. A taste panel was used to evaluate varieties for fruit quality (firmness, juiciness, crispness, toughness, flouriness), taste (sweetness and acidity) and appearance (shape and colour). Pinova was rated the best variety, followed by Rubinola, Liberty and Bohemia, although there were some concerns on skin finish and colour. The varieties Rajka, Ceeval, Florina and Delorina received only average ratings. Ecolette and Red Falstaff received ratings of 'indifferent' and Pilot and Topaz were rated poorly. There were wide ranging and mixed opinions on the quality of many varieties and in some cases only a very small panel was used to evaluate the fruit. UK-grown cultivars, including culinary varieties not assessed during 2002 and varieties sourced from abroad were scheduled for assessment in 2003.

Preliminary air storage trials
Preliminary storage trials were carried out on available fruit samples from UK-grown varieties during 2002. Varieties were held in air storage at different temperatures of

0-0.5°C, 1.5-2°C and 3°C. Five fruits of each variety were removed for testing during mid-November, mid-December and end-January. There did not appear to be any low temperature breakdown or adverse reactions to low temperatures in any variety and no other physiological disorders were noted. Fruits stored at the lowest temperature of 0-0.5°C retained the best firmness with the variety Pilot holding firmness exceptionally well in all temperatures. Preliminary results suggested that the best keeping varieties in air (at 0-0.5°C) were Pilot, Pinova, Ecolette, Delorina, Liberty and the culinary variety Pikant. Varieties Topaz, Santana and culinary varieties Encore and Howgate Wonder kept reasonably well until December. Rajka, Florina and Red Falstaff performed relatively poorly in all temperature regimes. There were not sufficient fruits of the varieties Edward VII, Ceeval and Rubinola for inclusion in the storage trials and only enough fruits of Bohemia to include in one temperature regime. The remaining varieties were therefore scheduled to be tested in 2003, along with fruits of varieties sourced from abroad (subject to sufficient fruits being available). Further storage work including CA storage was planned for the most promising varieties.

Year 4

Progress with variety trial on VF216

Many trees in the organic apple variety planting (VF216) produced a first light crop of fruit during 2003, some of which required hand thinning. Most of the trees had now established, with others re-grafted to compensate for losses due to canker or poor establishment. Half of the trial (blocks I, IV & V) continued to receive applications of sulphur from March – August 2003. Compost was applied to the crop rows in March to boost fertility and a *Bt* spray to control moth pests was also applied in May. A pest and disease assessment, carried out in June, revealed that although the plantation was still relatively young, differences in varietal sensitivity to pests and diseases were beginning to become apparent. Varieties most prone to mildew in 2003 were Goldrush, DL11, Liberty, Bohemia and Pinova. As in 2002, applications of sulphur reduced the incidence of mildew, although cultivar differences failed to reach statistical significance.

In addition to the pest and disease assessments carried out on VF216, shoot growth measurements and a record of precocity (cropping), overall growth and tree habit were also carried out during 2003. Varieties that were most vigorous in terms of shoot growth were Ariwa, Judeline, Delorina, Florina and Worcester Pearmain. Most varieties have also established a reasonably good framework. In terms of precocity, the varieties Ariwa, Red Falstaff, Pinova, Rebella and Delorina were the earliest to bear fruit in 2003, although grafting material used in the initial stages of propagation was likely to be influencing variety performance at that early stage.

Continued evaluation of promising apple varieties

Fruit samples of selected varieties were supplied to Sainsbury's and Waitrose from August – November for taste test assessment during 2003. The varieties Ceeval, Resi, Rubinola, Ariwa and Delorina received the best ratings for overall acceptability. Discovery, Rubinstep, Rajka, Pinova, Red Falstaff and Liberty received average – good ratings. Each variety was reviewed in detail during a meeting with fruit technologists during November and having taken into consideration each variety's performance in previous years, the decision was taken to eliminate varieties that had

performed relatively poorly in taste test assessments. These included the varieties Worcester Pearmain, DL11, Rebella, Santana, D3 (Free Redstar), Florina, Bohemia, Pilot, Topaz and Goldrush. The culinary varieties Edward VII, Encore, Howgate Wonder and Pikant were deemed suitable for fresh sales, provided that not too much top colour was present. Eleven dessert apples were short-listed to be evaluated in large scale taste test assessments at the Sainsbury's Centre in 2004, with a view to eventually selecting the best 4-6 for recommendation to growers at the end of the year.

Preliminary CA storage trials

Preliminary CA (1.5-2ºC, <1% CO2 + 2%O2) storage trials were carried out on fruits of the promising varieties, where available. Of the most promising apple varieties remaining on the short-list, the varieties Ariwa, Pinova, Rubinstep, Resi and Rubinola appeared to perform well in CA and were deemed likely to be suitable for long-term storage of at least four months (Ariwa and Pinova appear ed suitable for six month storage). Resi was the only variety to show any adverse reaction to the low temperature of 1.5-2ºC. The varieties Red Falstaff, Rajka and Liberty maintained an acceptable firmness of around 60 N for a 4 month period but were unsuitable for long-term keeping. The culinary apples Edward VII and Pikant retained good firmness in CA over four months, but the juicing variety Judeline appeared to be unsuitable for long-term storage.

Year 5 (final year)

Pests and diseases on VF216

Pest and disease assessments carried out on VF216 during mid-July showed some clear differences in varietal sensitivity to scab and mildew. Rosy apple aphid also continued to be a slight problem on the site. Despite the wet spring, incidence of scab on both leaves and fruit was low on most varieties. The highest incidence occurred on Pilot and Pinova with small amounts of both leaf and fruit scab found on Bohemia, Ecolette, Encore, Red Falstaff, Worcester Pearmain and Santana. Low levels of leaf scab were also found on Rubinstep and low levels of fruit scab were found on Ceeval, Discovery and Judeline. Secondary mildew was evident on all varieties with marked variations in severity. As usual, Goldrush was the most severely affected variety. The varieties Delorina, DL11, Liberty and Ariwa also had relatively high levels of infection. Varieties showing least amount of infection were Rajka, Edward VII, D3, Discovery, Rebella, Worcester Pearmain and Howgate Wonder. Rosy apple aphid was the most common insect pest and most varieties were affected with the exception of Delorina, Goldrush, Liberty, Red Falstaff (grafted 2002) and Rubinola. Rubinstep was the most severely affected variety but it is known to be particularly prone to the pest. Distribution of green apple aphid and other insect pests appeared to be relatively low and erratic.

Agronomic performance of varieties

Measurements of shoot growth taken during winter 2004-2005 show that the varieties Bohemia, Howgate, Worcester Pearmain, Rubinstep and Ariwa were the most productive in terms of new shoot growth during 2004 (and also the previous year). The variety Rajka made the poorest growth during 2004 (and also during 2003) but this may have been due to poor quality graftwood or lack of vigour during establishment.

Records of bloom density and flowering stage taken during April 2004 gave a good indication of the likely pollination group of each variety. Most varieties were between the pink bud and 50% bloom stage, indicating that they would be likely to fall into 'normal' pollination groups of 2 and 3. Florina was the most advanced variety with 90% bloom. Ceeval and Rajka were also relatively early flowering with 70% bloom. The least advanced variety in terms of flowering was Edward VII, which was still at the green cluster stage. Delorina was also relatively late at the green cluster – pink bud stage. The varieties Florina, Judeline, Liberty, Pilot, Pinova, Red Falstaff and Resi all had a very heavy bloom set during the spring. This was reflected in later observations of crop load at harvest.

Observations on variety form and habit continue to show that most of the varieties are upright-spreading in habit, although vigour continued to vary greatly between variety. Most varieties made good extension growth during 2004. The promising variety Rubinola continued to perform rather poorly (weak vigour, little growth, very light crop) although this may be due to susceptibility to canker or poor quality grafting material. It would be interesting to try both Rajka and Rubinola on more invigorating rootstocks such as MM106 or M26 to see if tree establishment and growth can be improved.

Final taste-test evaluations and identification of best varieties

The results from the Sainsbury's product testing evaluations show that out of the eleven dessert varieties evaluated using two-way comparison testing, the varieties Rubinola, Rubinstep, Pinova and Rajka achieved the highest overall scores respectively for attribute ratings (appearance, shape, colour, flavour and texture). Delorina, Resi and Ceeval also achieved relatively high overall scores. Rubinstep was evaluated in a single test without comparison with an accompanying variety, although the eventual scores achieved by the variety were compared to a mean of all previous varieties tested to give an indication of its performance.

Rubinstep was the most popular variety with 76% of consumers responding positively, with either a 'definite' or 'probable' response when asked if they would buy the apple again. Rubinola and Pinova were also popular with a 73% and 70% positive response respectively. The least favoured varieties were Discovery, Red Falstaff and Liberty where more than half of the consumers involved in the questionnaire stated that they would either not buy it, or weren't sure if they would. However, it was noted that at the time of the evaluation, Discovery was likely to be past its best, having been held in cold storage for too long prior to evaluation.

Six varieties were also evaluated by a small panel of fruit technologists at Waitrose, using a standard sensory profiling sheet which recorded scores for firmness, juiciness, crispness, toughness, flouriness, sweetness and acidity for each variety. Of the varieties evaluated, Ariwa and Pinova scored highest for firmness, with Ariwa also achieving the highest average score for crispness. Pinova was found to be rather tough. Rubinstep achieved a high score for sweetness. However, there was very little difference generally between most varieties and an average overall rating of 'pleasant' was awarded to the varieties Red Falstaff, Ariwa, Pinova and Rubinstep. Rubinola and Liberty achieved ratings of 'indifferent.' Not all varieties could be evaluated at Waitrose due to fruit damage in transit and staff time constraints.

Following the variety evaluations by Sainsbury's and Waitrose in 2004, a meeting held at the Sainsbury's Centre in December discussed the results of the product testing evaluations and review the varieties in detail. It was agreed that of the final eleven varieties evaluated during the year, the varieties Ceeval, Rajka, Resi, Rubinola and Rubinstep would be recommended to growers. Although the variety Pinova had performed consistently well in taste tests over successive years, it was agreed that the variety would not be recommended due to its lack of disease resistance. It was also agreed that the early season variety Discovery would be recommended for non-supermarket sales only and that the late-season variety Delorina would not be recommended, but would, however, be retained for further evaluation, along with the popular European organic variety Topaz. All other varieties were considered to be of insufficient quality for supermarket sales.

Previous evaluations have shown that four culinary varieties (Edward VII, Encore, Howgate Wonder and Pikant) would be suitable for processing and also for fresh market sales. It is still too early to tell if these varieties are any good for commercial organic growing, and ideally their agronomic performance needs to be evaluated on a larger scale. The French juicing variety Judeline has shown promise as a highly productive and disease resistant variety, but has a short shelf-life, which may put potential growers off trying the variety. If a juicing variety is to be selected for organic production, it is likely that growers will continue to choose varieties which are known to express sufficient volumes of juice (e.g. Fiesta, Red Falstaff) and are relatively easy to grow under organic protocols (tolerance to pests and diseases).

(See Appendix 4 for full database of short-listed dessert and culinary varieties).

ACTION POINTS FOR GROWERS (OBJECTIVE 2, FINAL REPORT)

Selection of varieties

- When selecting suitable dessert apple varieties for organic production specifically for volume sales through the multiple retailers in the UK, the chosen variety/ies should have a combination of the following attributes (in order of priority);

1) A good balance of fruit quality characteristics (e.g. colour, shape, firmness, juiciness, crispness, flavour).
2) Resistance or tolerance to scab, and also preferably to mildew.
3) No great sensitivity to important apple pests, particularly those for which no satisfactory control measure exists under organic protocols.
4) No great sensitivity to other apple pathogens, such as canker (*Nectria galligena*).
5) Ability to yield precociously, productively and consistently, with well-size fruit (>60mm diameter).
6) Suitability for short or long term fruit storage (depending on season).

Identification of suitable varieties from HortLINK project 237/3

Over 150 disease resistant or promising apple varieties were evaluated for their suitability for organic production in the UK during the project from 2000-2004. This was achieved primarily by screening apples for eating quality through a series of evaluations involving consortium partners including Waitrose and Sainsbury's. Identifying varieties acceptable to UK consumers was the most important component of the work. A short-list of 28 promising varieties were also evaluated for their performance in an organically managed trial orchard, where records of pest and disease susceptibility and agronomic performance were taken.

Recommended dessert varieties

The varieties Ceeval (early season), Rajka, Resi, Rubinola and Rubinstep (mid season) were identified as the most promising dessert varieties for organic production after 4 years of evaluation. They were deemed the best varieties in terms of eating quality and likely consumer acceptance. In addition, each also has a reputed resistance or tolerance to scab (*Venturia inaequalis*), although mildew is likely to remain a problem on all varieties. Key points for each variety are listed below. Full details can be found in Appendix 4 of the final project report (variety database).

Ceeval (Red Alkmene / Red Windsor)
This is a highly coloured clone of Alkmene (Early Windsor) with many Cox attributes. Harvest is from early September (same season as Worcester). Fruit ripening can be erratic so trees may need picking-over several times and fruit size can be variable (thinning is advised). Fruit quality is very good but fruits should be marketed within several weeks of harvest (short-term storage only). Trees show a good tolerance of scab, although fruit scab may occur in high scab risk years. Reputed resistance to mildew – although our trials have not found this to be the case. Cropping is heavy, although trees may crop lightly during early years.

Rajka
A relatively new, disease resistant apple variety from Czech Republic. Rajka is a mid-season variety (harvest mid-September) with a relatively short storage life (4 months max in air and CA). Fruits have a very good flavour, but a tendency towards greasiness if over-mature. The variety is scab resistant with a good tolerance of mildew. Rajka is easy to grow, with a vigorous, free-spurring habit, suitable for most rootstocks, and is a good pollinator for other varieties.

Resi
A scab resistant variety from the Dresden-Pillnitz breeding programme in Germany, also with some tolerance of mildew. Resi is a mid-season variety and stores reasonably well although has a tendency to develop soft scald if stored below temperatures of 2°C (more work needs to be done to modify the CA regime). Fruits are Gala-like in appearance, very attractive, with a dense, crisp flesh and high juice levels. Fruits are produced on long stalks. Tends to over-crop with small fruits, so thinning is essential to maintain good fruit size. Trees are precocious, vigorous and productive. A very good pollinator for other varieties.

Rubinola
A high-quality mid season dessert variety from Czech Republic. Rubinola has reputed scab resistance and a high tolerance of mildew, but appears susceptible to canker and has been noted to suffer from leaf spot (*Phoma*) on fruits. Eating quality is excellent. Fruits are extremely crisp, juicy with a moderately acid flavour and excellent storage potential (post Christmas). Tends to become greasy-skinned if over-mature, but this does not affect eating quality. Fruits are very attractive – large, flat-round with 70% top red colour over orange/yellow background. Tree performance has been variable in trials at EMR but the variety is reputed to be vigorous, requiring a rootstock weaker than M9 to curb its vigorous growth. Can be inclined to tip-bearing fruiting habit.

Rubinstep
Another variety from the Czech Republic with polygenic scab resistance, although the variety does appear to be prone to rosy apple aphid. Similar to Rubinola, fruits have excellent eating and visual quality and excellent storage potential (post Christmas). Fruits are very crisp and well flavoured. Some russet may be present around the stalk end. Trees are reputed to be extremely vigorous and a dwarfing rootstock such as M27 and M9 may need to be used to curb vigour. Cropping is moderate – thinning not usually required. Trees can be slow to come into bearing.

Recommended culinary varieties

During the project, over 30 varieties of culinary apple (initially selected on the basis of having some merit for organic production) were evaluated for their potential for processing, by staff from Fourayes Farms. Only those varieties which had good fruit quality for pie-making and were of sufficient size to be handled efficiently by industrial peelers and slicers were short-listed as acceptable. Visual quality (for potential fresh sales) was also assessed by staff from Sainsbury's and Waitrose.

The varieties Edward V11, Encore, Howgate Wonder and Pikant were identified as the most promising culinary varieties for organic production after 4 years of evaluation. They were deemed the best varieties in terms of processing / cooking quality and likely consumer acceptance as an alternative to Bramley when used in fresh sales, provided not too much top (red) colour is present. The varieties Edward VII, Encore and Pikant also have a reputed resistance or tolerance to scab (*Venturia inaequalis*), although mildew is likely to remain a problem. In contrast, Howgate Wonder has reputed resistance to mildew, but may suffer from scab. Key points for each variety are listed below. Full details can be found in Appendix 4 of the final project report (variety database).

Edward VII
A late-season culinary apple, similar in colour and shape to Bramley, although with more of an orange flush over green background. Breaks down to a creamy puree when cooked. Good resistance to scab, although may suffer from bitter pit. Flesh is firm but rather coarse textured, juicy and acidic (although not as acidic as Bramley). Cooking and processing quality is good. Trees can be rather slow to come into bearing and may be difficult to crop in some situations. Trees are compact in habit and hardy, but very late flowering. Storage life is reputed to be good, although scald can be a problem at some temperatures.

Encore
A scab resistant, late-very late season culinary apple with a brownish-red flush over blotchy green background. Fruits can be very large. Flesh is high quality – juicy and subacid with a rather coarse texture and rich flavour. Remains intact when cooked. Cropping is good and the trees are moderately vigorous, spurring freely. Storage is short-term only (2 months in air and CA).

Howgate wonder
A late season culinary apple with reputed resistance to mildew and a very high tolerance of frost. One of the largest cooking apples in cultivation. Brownish-red flush over most of the skin surface with broad broken stripes of dark red or scarlet. Flesh is very firm and fine-textured, becomes sweeter in storage. Cooks well and breaks up almost completely. Cropping is heavy and regular when fully established. Stores well but becomes very greasy.

Pikant
A new dual-purpose mid season apple from the Dresden-Pillnitz breeding programme in Germany. Produces very large sized fruits with a solid red flush (50-90%) over yellow background. Good sugar-acid balance. Flesh is firm and crisp and well-flavoured with a good sugar-acid balance, suitable for processing. Trees are vigorous and productive, requiring dwarfing to medium vigour rootstocks. Cropping is heavy but fruit size and ripening can be variable so thinning is usually required so maximise fruit size. Fruits can be stored until Christmas in air and until Jan/Feb in CA. Only slight susceptibility to scab and mildew.

Juicing varieties

The French variety Judeline, a highly disease resistant and productive cultivar which produces fruits of high juice content with a good sugar – acid balance, was initially selected as having potential for juicing. However, further trials revealed that the variety has an extremely limited storage life, and is therefore not likely to be acceptable for large-scale commercial juice production. It is likely that varieties which express a good volume of juice (e.g. Red Falstaff and Fiesta) and which are less susceptible to the diseases scab and mildew will continue to fill the organic juice market.

Pest and disease resistance

The variety trial VF216, planted with 28 promising varieties selected by Sainsbury's and Waitrose during the first two years of the project has proved that it is very difficult to select varieties with complete resistance to both scab and mildew and reputed genetic resistance to disease cannot be solely relied on to protect the variety from infection. Varieties with polygenic (multi-gene) resistance to scab are more favourable than single gene (*Vf*) types, but even this cannot guarantee immunity to some scab races, which can overcome resistance. Mildew was an acute problem for many of the varieties on VF216 and was apparent in the orchard right from planting. Few varieties are resistant. The fungus was particularly crippling to young trees during establishment, resulting in weak, distorted growth and failure of the trees to grow well. Scab took slightly longer to progress into the new variety planting and was most likely hampered by the mix of varieties with varying degrees of resistance.

Resistance or tolerance to common pests such as rosy apple aphid is a desirable trait for organic production, but cannot be relied on to provide an effective threshold to infestation in years of heavy pest pressure.

It is highly recommended that, where varieties are selected for organic production, pest and disease resistance or tolerance should be regarded as an extremely important component, but should not be relied upon wholly as a guarantee of immunity. Ideally resistant / tolerant varieties should be used in conjunction with a suitable preventive spray programme of permitted plant protection products in order to provide effective control in years of heavy pest or disease pressure.

Planting a new orchard

When planting a new orchard, it is essential to start off with strong, robust trees on a semi-vigorous rootstock (e.g. MM106) which can compete successfully with the orchard sward. The project has shown that the use of young bench-grafted trees planted too early straight into a grass sward is likely to lead to tree losses and failure to establish well due to competition for water and nutrients. It is essential to consider methods of weed control during tree establishment to allow the trees to receive the best possible start.

Objective 3: Testing alternative chemicals against apple scab and powdery mildew

SUMMARY (OBJECTIVE 3, FINAL REPORT)

Experiments were conducted in glasshouse compartments or polytunnels to investigate the efficacy of several organic-compatible chemicals in controlling apple powdery mildew and apple scab when applied as a protectant, curative and antisporulant fungicide. Several products resulted in statistically significantly reduction of mildew or scab severity; however, the reduction in disease severity achieved by these products, compared to the untreated or fungicides, was very small and still unacceptable in commercial organic production. Only two traditional products, copper and sulphur, controlled scab and mildew effectively. We conclude that in the UK where environmental conditions are very conducive to scab and mildew epidemics, the only feasible solution to control scab and mildew in organic production is to grow cultivars which are resistant to the diseases, especially scab.

INTRODUCTION (OBJECTIVE 3, FINAL REPORT)

One of the main reasons for the poor performance of current organic apple production methods is inadequate pest and disease control. Apples are subject to attack by a wide range of highly damaging pests and diseases. The diseases scab and mildew are particularly debilitating. They severely reduce tree growth, yield and quality. In conventional production, they can be managed satisfactorily by fungicides coupled with disease warnings generated by Adem™ (Berrie & Xu, 2003). The range of plant protection products available for disease control in organic production in the UK is very limited (copper carbonate and oxychloride, potassium soap, sulphur). There is an urgent need to discover novel organic-compatible products that can effectively be used to manage apple scab and mildew.

There is a considerable range of plant protection products based on clay, mineral, compost and algal extracts that are claimed to have fungicidal properties against diseases on several crops (Fallik *et al.*, 1997a; Fallik *et al.*, 1997b; Pasini *et al.*, 1997; Petsikos-Panayotarou *et al.*, 2002; Scheuerell & Mahaffee, 2002; Gamagae *et al.*, 2003; Mann *et al.*, 2004). Recent work in Australia has also suggested that raising the pH of the leaf and fruit surface controls scab and they used calcium hydroxide but maybe sodium bicarbonate is a safer alternative. Most reports on controlling diseases by natural products often do not provide sufficient details, which do not instil the confidence on some claims resulting from these studies. It is essential that we should investigate the effectiveness of various alternative products in controlling apple scab and powdery mildew in the UK conditions.

METHODS AND MATERIALS (OBJECTIVE 3, FINAL REPORT)

This study was conducted in three phases. A wider range of products were included in the first phase, but less effective/useful ones were discarded in subsequent

experiments to enable a more detailed study of the most promising ones. Table 3.1 gives the alternative chemicals tested in this research. In the first phase, preliminary experiments were conducted in glasshouse compartments or polytunnels to investigate the efficacy of selected organic-compatible chemicals in controlling apple powdery mildew and apple scab when applied as a protectant, curative and antisporulant fungicide using MM106 rootstock plants. In the second phase, experiments were conducted on small potted trees in a sand-bed to determine the activity and relative persistence of the alternative products selected from the first phase experiments. Finally, a few products were selected and taken further to orchard trials.

New products were constantly added to the screening experiments, particularly in the first phase experiments, during the entire five-year period. Hence, not all products were evaluated in a single experiment. Therefore, the efficacy of the products was only compared with the untreated controls within the same experiment.

First phase on rootstock plants

Plant materials and inoculation

Rootstock MM106 plants were used for testing; they were potted up in batches and grown in a 'mildew-free' and 'scab-free' glasshouse compartment at about 20°C (18-23°C) and 70% relative humidity (rh) with a 16 h light/8 h dark daily regime. Leaf positions were identified by tagging the youngest fully unrolled leaf at the time of inoculation or spraying. Plants were randomly placed in the compartment/polytunnel before spray application.

For powdery mildew, on each plant to be inoculated, the shoot tip was labelled; the four youngest leaves on each labelled shoot tip were inoculated by shaking conidia from the mildew-infected leaves onto their surface. For apple scab, conidia were washed off previously infected and stored leaves with distilled water; a spore suspension was prepared with its spore concentration adjusted to $2.5x10^5$ conidia per ml. Inoculation was conducted in glasshouse compartments (*c*. 25 m^2) with three misting nozzles to maintain surface wetness (high humidity). Misting nozzles were switched on immediately after inoculation and turned off 24 hours later (i.e. giving 24 h duration of wetness). The tagged shoot tip was sprayed with the spore suspension using a fine hand-held aerosol sprayer. Each shoot tip received approximately 0.3 ml spore suspension, i.e. approximately 75000 conidia, which thoroughly wetted the shoot tip.

Treatments

We conducted three separate experiments in this phase. In the first experiment, ten chemicals were included for testing: $Ca(OH)_2$, Milk, Herb silica, Liquid silica, Ulmasud B, Mycosin, Neudo vital, Sulphur, Wetcol 3 and Equisetum. They were applied either at 100% of the labelled recommended full rate and at the rate used in previous research (Table 3.1). In addition to these chemicals, two control treatments were also included: water-treatment and untreated. The second experiment was conducted to investigate the efficacy of compost teas in controlling apple powdery mildew and apple scab when applied as a protectant fungicide. We have tested compost tea in a mixture with a wetter chemical (Agral) as well as on its own. In total, there were seven treatments: fungal compost tea with or without Agral, bacterial compost tea with or without Agral, Systhane, Agral and untreated. In the third

experiment, the efficacy of Serenade against scab was evaluated. In all three experiments, a complete randomised design was used and the experiments were repeated. In each repeat, there were at least three plants each with up to 11 shoots for each treatment.

In the first experiment, each chemical was tested as a protectant, curative and anti-sporulant treatment against powdery mildew, and as a protectant and curative treatment against scab. For the protectant test, chemicals were first applied with a hand-held sprayer to the tagged shoots until runoff. Then these treated shoots were inoculated with scab conidia 3 or 8 days after the spray, or with mildew conidia 4 or 8 days after spray. For testing curative effects, selected shoots were first inoculated with mildew or conidia and then treated with chemicals 2 or 4 days later. For anti-sporulant testing, chemicals were similarly applied to sporulating mildew colonies on rootstock plants; these colonies resulted from inoculation done 14 days before the application of chemicals. In the second experiment, only the protectant effects were evaluated: products were applied 1 day after inoculation. For the Serenade test against scab, plants were either treated with Serenade 2 days before inoculation or inoculated 2 days before being treated with Serenade.

Table 3.1 Products used in the screening studies and their rate of use

Product	**Concentration**	**Rate/L**	**Phase of the study**
Mycosin	1%	10 ml/L	1
Ulmasud B	2%	20 ml/L	1
Herb silica	5 L/ha	2.5 ml/L	1
$Ca(OH)_2$	4 kg/100L	40 g/L	1
Headland Sulphur	560 ml/100L	5.6 ml/L	1-3
Neudo vital	5 ml /500 ml	10 ml/L	1
Lime Sulphur		15 g/L	2
Equisetum	2%	20 ml/L	1
Wetcol 3	50 L/1000L	50 ml/L	1-3
Milk	50%	500 ml/L	1
Milsana	1.2%	12 ml/L	1-3
Serenade	6 kg/ha	6 g/L	1-3
Liquid silica	5L/ha	2.5 ml/L	1-3
Compost Tea – Fungal		100 ml/L	1, 3
Compost Tea – Fungal		100 ml/L	1, 3
MaxCrop		100 ml/L	3
Polyversum		0.5 g/L	2
Farmphos		2.5 ml/L	2

Disease assessment

Scab was assessed on each of all the fully unrolled leaves above the tag (including the tagged leaf) on each inoculated shoot tip, up to a maximum of five leaves for rootstock plants. The upper surfaces of each leaf were examined for scab colonies 12-14 days after inoculation and the approximate percentage of leaf area with scab colonies was recorded for each leaf. The number of mildew colonies were counted on each leaf of the treated shoots from the leaf '0' (youngest fully extended leaf) to the tagged leaf about 10-14 days after inoculation for the protective/persistence and curative tests. For antisporulant tests, 10-14 days after treatment, roughly 3 cm^2 pieces of sticky tape were cut and put on the top of the treated lesions; they were then peeled off and stuck onto glass slides. The imprint of mildew colonies left on the sticky tape was examined under a microscope. The percentage of healthy (non-damaged) mildew conidia was estimated by examining 50 conidia per slide.

Second phase on potted trees

Experiments in this phase were conducted over two years (2001 and 2002). In the sand-bed tests, no artificial inoculation was used and hence disease development relied on natural inoculum and infections.

In 2001, several products were selected on the basis of glasshouse results for testing to evaluate their efficacy against powdery mildew and scab on potted trees of 5-year-old cv. Queen Cox. Products tested were Headland sulphur, Lime sulphur, Wetcol 3, Milsana and Liquid silica. In addition, Systhane and an untreated control were also included. They were sprayed every 10 days from June 8th until 30th July 2001, a total of 6 times. Polyversum, a root drench treatment and kindly donated by Peter Hall, was also applied from 28th June, a total of four times. There were 10 trees per treatment.

Eight growing shoots were labelled per tree and the fruits removed to encourage them to keep growing. On each tree, the tip of each labelled shoot was sprayed with an appropriate product. On each tree scab and mildew were assessed on five shoots, randomly chosen from the eight treated shoots, on 22nd June, 6th July and 10th August. On the first two occasions leaves '–1' to '–4' were recorded for number of lesions. For the last record leaves '–1' to '-8' were recorded, again, for number of lesions for the two diseases. A random block design was used with two blocks. Within each block, there were five trees for each treatment.

In 2002, tests were conducted on potted trees of 5-year-old cv. Queen Cox and 3-year-old cv. Gala to evaluate the following products: Wetcol (pre-bud burst application), Wetcol, Distillery by-product, FarmFos42, Headland Sulphur, Lime Sulphur, Liquid Silica, Milsana, Polyversum and Serenade. As in 2001, Systhane and an untreated control were also included. They were sprayed every 10 days from bud-burst until 30th July 2002, a total of 12 times, except the bud-burst application of Wetcol 3. There were eight trees (five Cox and three Gala) per treatment.

Unlike in 2001, the whole tree was sprayed thoroughly with an appropriate product. On each tree, five shoots were randomly chosen for assessment of scab and mildew in mid-May. In August, diseases on both leaves and fruits were assessed. Leaves '–1' to '–4' were recorded for number of lesions of scab and mildew whereas all fruit on each tree were assessed for fruit scab.

Orchard test

Orchard evaluation was carried out in 2003 and 2004 in an organic orchard (VF211) at East Malling Research. In 2003, seven products were evaluated: early copper (Wetcol) at pre-bud-burst, routine copper at low rate, Milsana, Serenade, Liquid Silica, Sulphur and compost tea. Unfortunately, the compost tea making facility was not delivered from The Netherlands until mid-July and hence compost tea was not included as a treatment. In addition, an untreated control was also included. Tests were conducted on two cultivars: Red Pippin and Saturn. The orchard was divided into three blocks and in each block there were three trees of each cultivar for each treatment. From April, each product (apart the early copper treatment) was applied routinely (every 10-14 days weather permitting). However, in early summer, because of bad weather (either too windy or wet), this interval of spray was not possible.

Scab and mildew were assessed three times: June, July and August. For each assessment, one tree from each cultivar in each block, located in the middle of the three trees, was assessed for each treatment. For assessing mildew, five shoots were randomly selected and presence of mildew was recorded on the top five fully unrolled leaves. For scab assessment, it was the same as mildew for the first two assessments whereas only fruit scab was assessed in the last assessment. All the fruits on the tree were assessed for the presence of scab lesions and number of scab lesions was counted on those infected fruits.

In 2004, nine treatments were evaluated in the same orchard as in 2003: fungal compost tea, bacterial compost tea, Maxicrop, three pair-wise combinations of Liquid Silica, Maxicrop and Milsana, Sulphur and untreated. These were selected on the basis of results obtained in the previous years and the suggestions from the consortium. Again, each treatment was evaluated on both Red Pippin and Saturn. The orchard was divided into two blocks and in each block each treatment had four trees for each of the two varieties. From April, each product was applied routinely (every 10-14 days weather permitting). However, by the time of early June, mildew was very severe and incidence of fruit scab on Red Pippin was very high, the experiment was hence terminated then.

Scab and mildew were assessed in early June. Two trees from each block of each cultivar, located in the middle of the four trees, were assessed for each treatment. For mildew assessment, five shoots were randomly selected and presence of mildew was recorded on the top five fully unrolled leaves. For scab assessment on leaves, it was the same as mildew. For the assessment of fruit scab, all the fruits on the tree were assessed for the presence of scab lesions and number of scab lesions was counted on those infected fruits.

Statistical analysis

Disease incidence data (p), i.e. proportion of leaves or fruit infected, were logit-transformed ($\ln\left(\frac{p}{1-p}\right)$) before analysis of variance. Disease density data, i.e. number of colonies per leaf/fruit, were logarithm-transformed before analysis of variance. Analysis of variance was used to assess the overall significance of treatment effects. The significance of each pair-wise treatment difference was evaluated using the least significant different (LSD) test on the transformed scale.

RESULTS (OBJECTIVE 3, FINAL REPORT)

Rootstock (glasshouse test)

Table 3.2 presents the summary of the protectant tests in the first experiment. Overall there were significant differences between treatments in both scab and mildew severity. Several products had significantly reduced the number of mildew lesions, compared to the untreated; these included $Ca(OH)_2$, Sulphur, Wetcol 3. In contrast, none of treatments had significant control effects on scab; indeed several products apparently significantly increased the scab severity.

Table 3.2 Average number of mildew lesions or average percentage of scabbed leaf area on each treated/inoculated leaf in the testing for protective action of the chemicals on MM106 rootstock. There were no significant differences between treatments with the same letter after their means (LSD tests).

	Powdery mildew		Scab (%)	
	1-4 days	5-8 days	3 days	8 days
$Ca(OH)_2$	1.3 ab	2.2 ab	9.8 d	0.5 a
Equisetum	12.1 b	5.0 bc	8.2 cd	5.6 c
Herb silica	12.2 b	5.4 bc	9.5 d	2.9 abc
Liquid silica	4.1 ab	8.0 c	8.8 cd	2.0 abc
Milk	7.5 ab	2.2 ab	8.2 cd	4.5 bc
Mycosin	11.0 ab	4.2 bc	4.4 bc	2.4 abc
Neudo Vital	13.0 b	8.8 c	3.9 abc	3.0 abc
Sulphur	0.1 a	0.1 a	0.7 ab	2.3 abc
Ulmasud B	6.6 ab	4.7 abc	4.4 cd	1.7 abc
Untreated	8.8 ab	8.6c	3.3 ab	1.8 ab
Water	8.8 ab	6.1 bc	6.2 cd	0.8 ab
Wetcol 3	3.6 ab	4.9 ab	0.5 a	1.9 ab

Table 3.3 presents the summary of the curative tests in the first experiment. Overall there were significant differences between treatments in both scab and mildew severity. However, none of the products showed any significant curative control effects against either scab or mildew. Similarly, none of the treatments had significant anti-sporulant effects against mildew, except Ulmasud B (Table 3.3).

Table 3.3 Average number of mildew lesions or average percentage of scabbed leaf area on each treated/inoculated leaf in the testing for curative action of the chemicals on MM106 rootstock as well as antisproulant effects (expressed as average percentage of healthy conidia on colonies sampled 10 days after chemical application). There were no significant differences between treatments with the same letter after their means (LSD tests).

	Powdery mildew			Scab (%)	
	2 days	4 days	Antisporulant	2 days	4 days
$Ca(OH)_2$	0.9 ab	5.5 abc	76.9 abc	0.00 a	0.15
Equisetum	10.7 c	15.9 c	87.8 bc	0.04 a	0.69
Herb silica	7.3 bc	11.5 bc	77.1 ab	0.02 a	0.01
Liquid silica	1.8 ab	6.9 abc	91.3 c	0.01 a	0.24
Milk	4.4 abc	8.6 abc	87.3 bc	0.02 a	0.36
Mycosin	2.3 ab	3.0 abc	77.3 abc	0.46 b	0.17
Neudo Vital	4.7 abc	11.9 abc	75.3 ab	0.05 a	0.06
Sulphur	0.0 a	0.0 a	82.4 abc	0.01 a	0.15
Ulmasud B	1.4 ab	11.2 bc	67.7 a	0.20 a	0.05
Untreated	3.2 ab	9.8 abc	89.1 bc	0.01 a	0.20
Water	2.3 ab	6.1 abc	90.2 bc	0.30 a	0.55
Wetcol 3	0.4 a	2.0 ab	75.8 ab	0.01 a	0.22

Table 3.4 gives the summary of the second experiment using compost tea products. None of the alternative products had any harmful effects on scab and mildew development. Indeed, the combination of Agral and bacterial compost tea resulted in even greater incidence than the untreated ($P < 0.01$). Interestingly, Systhane did not control scab effectively either. Further tests indicted that the isolates used were not sensitive to Systhane (results not shown).

Table 3.4 Average number of mildew lesions and percentage of scabbed leaf area on each treated/inoculated leaf in the testing for protective action of the chemicals on MM106 rootstock. There were no significant differences between treatments with the same letter after their means (LSD tests).

Chemicals	Mildew	scab
Systhane	1.6 c	28.2 a
Untreated	23.5 a	30.0 a
Agral	35.8 a	22.6 a
Bacteria tea	36.8 a	27.8 a
Fungal tea	27.7 a	25.5 a
Bacterial tea + Agral	52.0 b	27.2 a
Fungal tea + Agral	25.5 a	25.3 a

Serenade did not reduce scab significantly compared with the untreated when applied either as a curative or protectant product (the third experiment).

Sand-bed tests

2001 Test

Apple Scab: Analysis of variance showed that there were no significant block effects for both years, and so data were pooled over the two blocks. Results from 2001 tests on potted trees of cv. Queen Cox are given in Table 3.5. For the first two assessments, scab lesions were only observed on a few leaves. There were also no significant differences between treatments. For the last assessments, only 202 out of 2270 leaves had developed scab lesions. However, there were significant differences between treatments (Table 3.5). All the treatments significantly reduced the number of lesions, compared with the untreated. Of the products tested, the two sulphur products and Wetcol 3 were the best; their performance is statistically similar to Systhane.

Table 3.5 Average number of scab lesions per leaf on potted 5-y-old trees of cv. Queen Cox in sandbed. Products were applied every ten days. There were no significant differences between treatments with the same letter after their means (LSD tests).

	Scab		Powdery mildew		
Products	1st & 2nd assessment	3rd assessment	1st assessment	2nd assessment	3rd assessment
Headland Sulphur	There were no significant differences between all the treatments.	0.196ab	0.28a	0.70b	0.54b
Lime Sulphur		0a	0.32ab	0.08a	0.12a
Liquid Silica		0.283bc	1.15d	1.40cd	1.13d
Milsana		0.680d	1.02d	1.63e	1.64d
Polyversum		0.473cd	*	1.33de	2.45f
Systhane		0.177b	0.35b	0.65a	0.34ab
Untreated		0.801e	1.43e	2.41f	2.01e
Wetcol 3		0.033a	0.73c	1.06c	1.01c

Apple powdery mildew: On the first assessment, mildew lesions were observed on 497 out of 1070 leaves. On those leaves with lesions, number of lesions ranged from 0 to 15. There were significant differences between treatments; treatment means are given in Table 3.5. All the treatments significantly reduced the number of mildew lesions, compared with the untreated. Of the products tested, the two sulphur products were the best and their performance is statistically similar to Systhane, with average 0.3 lesions per leaf compared to 1.4 lesions per leaf for the untreated control. Similar results were also obtained for the other two assessments (Table 3.5). In general, Lime Sulphur was the best and its efficacy is comparable to Systhane. All treatments except Polyversum had some efficacy against powdery mildew

2002 Test

Apple Scab: Table 3.6 shows the average number of scab lesions and incidence of scabbed leaves for each treatment when assessed in mid-May. ANOVA showed that there were no significant treatment effects. Gala had significantly more scab than Cox; there were no scabbed leaves on the bud-burst Wetcol treatment on Gala. However, the overall scab incidence was very low in May.

Table 3.6 Average number of scab lesions per leaf and incidence of scabbed leaves for each treatment whether alternative products were applied in sand-bed at a 10-day interval in 2002. Scab was assessed in mid-May. There were no significant differences between all the treatments.

Treatment	Cox		Gala	
	No of lesions/leaf	% leaves infected	No of lesions/leaf	% leaves infected
Pre-bud burst Wetcol	0	0	0	0
Distillery Waste	0	0	0.12	7%
FarmFos42	0	0	0.1	5%
Headland Sulphur	0	0	0.1	3%
Lime Sulphur	0.03	2%	0.03	2%
Liquid Silica	0	0	0.1	5%
Milsana	0	0	0.33	10%
Polyversum	0	0	0.5	5%
Serenade	0	0	0.05	2%
Systhane	0	0	0.02	2%
Untreated	0.03	3%	0.23	2%
Wetcol 3	0	0	0.18	7%

In the August assessment, virtually all fruits on the trees were scabbed. Thus it was not possible to assess incidence of fruit infection. Furthermore, most infected fruit had multiple lesions, many of which had merged. Therefore, it was not possible to count the number of lesions. For marketable yield, incidence and severity measures for scab are equivalent, i.e. a fruit with a single scab lesion is equally unmarketable as one with many lesions. Despite this fact, scab severity on fruits of trees treated with pre-bud break Wetcol did appear to be less than on other treatments. Because of difficulties in assessing diseases, we have taken digital pictures of each treatment to illustrate the severity of fruit scab (Figure 3.1). It is also interesting to note the poor skin finish associated with some treatments - sulphur, lime sulphur and Wetcol (routine).

Apple mildew: Table 3.7 shows the average number of mildew lesions per leaf for each treatment. ANOVA showed that there were significant treatment effects. Overall, all the treatments significantly reduced the number of mildew lesions, compared with the untreated. Of the products tested, the lime sulphur was the best and its performance was not statistically different from Systhane, with average 0.2 lesions per leaf compared to 1.2 lesions per leaf for the untreated control. Broadly speaking, the products can be divided into four groups with decreasing efficiencies: (1) Systhane, Sulphur, (2) Distillery waste, Liquid Silica, Serenade, Milsana, Wetcol 3, (3) FarmFos42, Polyversum, and (4) Bud burst Wetcol.

Table 3.7 Average number of mildew lesions per leaf and incidence (percentage) of leaves infected on potted 5-y-old tress of cv. Queen Cox and cv. Gala in a sand-bed in 2002. Products were applied every ten days.

Treatment	Cox		Gala	
	Lesions	Incidence	Lesions	Incidence
Pre-bud burst Wetcol	0.6	30%	1	40%
Distillery	0.19	16%	0.4	22%
FarmFos42	0.28	22%	0.9	47%
Headland Sulphur	0.15	13%	0.23	18%
Lime Sulphur	0.11	9%	0.23	6.7%
Liquid Silica	0.13	11%	0.82	28%
Milsana	0.06	6%	0.52	27%
Polyversum	0.35	21%	0.88	35%
Serenade	0.06	6%	0.77	37%
Systhane	0.06	4%	0	0
Untreated	0.32	24%	1.9	60%
Wetcol 3	0.18	14%	0.62	32%

In the August, assessment of mildew was made virtually impossible by the heavy presence of scab on leaves and by the general poor status of leaves. Therefore, no assessment was made.


Polyversum


Distillery Wash


Cox Budburst
Wetcol 3


Cox Budburst
Wetcol 3


Untreated


Headland
Sulphur


Liquid Silica


Lime Sulphur


Farm Fos

Figure 3.1. Photos of harvested fruit from potted 5-year-old Cox trees subjected to various treatments.

Orchard test

2003

Powdery mildew: In the June assessment, the percentage of mildewed leaves was very high, reaching 73% for the untreated. Only routine low copper had significantly less mildew (61%), whereas Liquid Silica and Milsana appeared to increase mildew (83%) on Red Pippin. Results on Saturn were generally similar apart from the fact that mildew level was generally lower than on Red Pippin (Table 3.8).

Table 3.8 Summary of mildew (% of leaves infected in June and July) epidemics on Red Pippin and Saturn, and fruit scab epidemics on Red Pippin trees subjected to various treatments in 2003.

	Mildew				Fruit scab	
	June		July		Incidence (%)	Lesions per infected fruit
	Red Pippin	Saturn	Red Pippin	Saturn		
Early Copper	76	56	97	59	16	1.6
Low Copper	61	56	92	47	5	3.3
Milsana	80	63	99	76	19	2.8
Serenade	73	60	97	73	22	3.2
Silica	83	63	100	63	13	3.6
Sulphur	72	59	91	42	2	2.5
Untreated	73	63	93	55	18	3.6

For the July assessment, almost all the leaves on Red Pippin were infected by mildew (Table 3.8). In contrast, mildew remained at the similar level to that in June on Saturn. In addition, both sulphur and low rate copper had significantly less mildew than untreated, whereas Milsana, Silica and Serenade resulted in significantly more mildew than untreated. Because of the hot weather in the summer, all the extension shoots stopped growth by the time of third assessment in August, hence the mildew was virtually unchanged from July.

Scab: There were no scab lesions observed on Saturn. There were very few leaves infected by scab particularly for the June assessment. Hence data on leaf scab were not presented. About 18% of fruit was infected with scab for the untreated. Of all the treatments, only the treatment (low rate copper and sulphur) had significantly reduced the scab incidence (5% and 2%, respectively) (Table 3.8). For early copper treatment, even though the incidence was similar to the untreated the severity of the scab was significantly less than the untreated: 1.6 lesions per infected fruit compared to 3.6 lesions per infected fruit.

2004

Powdery mildew. The percentage of mildewed leaves was very high; nearly all leaves were infected (Table 3.9). Of the treatments, five had significantly ($P < 0.05$) reduced the incidence of mildew; sulphur clearly was the most effective one (Table 3.9). However, even for these five treatments, the incidence of mildew was still too high. For example, about 60% of leaves were infected on Red Pippin treated with sulphur, compared to 99% of the untreated. Both types of compost teas did not reduce mildew

significantly. Results on Saturn were generally similar apart from the fact that mildew level is generally lower than on Red Pippin (Table 3.9).

Table 3.10. Percentage of leaves infected by powdery mildew and scab on VF211 field in 2004 (based on 100 leaves – 5 leaves per shoot – 5 shoots per tree) and fruit scab (based on all fruits from four trees per treatment, Red Pippin only). There were no significant differences between treatments with the same letter after their means (LSD tests).

Treatment	Fruit scab	LSD test (mildew)	Red pippin		Saturn	
			Mildew	Scab	Mildew	Scab
Compost Tea (bacteria)	47 de	ab	90	1	70	0
Compost tea (fungal)	54 e	a	94	3	70	0
Liquid silica + Maxicrop	50 d	abc	82	2	71	0
Liquid silica + Milsana	40 abc	bc	88	1	63	0
Low rate copper	10 ab	bcd	74	0	60	0
Maxicrop	45 e	ab	97	7	63	0
Maxicrop + Milsana	37 bcd	c	73	2	51	0
Sulphur	8 a	cd	60	3	19	0
Untreated	60 e	e	99	4	74	0

Scab. There were no scab lesions observed on Saturn. There were very few leaves infected by scab particularly for the June assessment (Table 3.9). Sulphur and low rate copper had resulted in lowest incidence of fruit scab. All other treatments had very high incidence (> 35%, Table 3.9), similar to the untreated.

DISCUSSION AND CONCLUSIONS (OBJECTIVE 3, FINAL REPORT)

Overall, it was very disappointing that almost all the alternative products tested during the five year period were not very effective in controlling apple mildew and scab, especially against scab. Of all the products tested, only sulphur and frequent application of low rate copper were effective against powdery mildew and scab, respectively. Interestingly, it also appears that sulphur was also effective against apple scab.

Several published research studies indicated that compost tea products controlled diseases in various crops (McQuilken *et al.*, 1994; Litterick *et al.*, 2004; Scheuerell & Mahaffee, 2004). However, it is also known that the efficacy of such control depends critically on many factors such as aeration, pH value, compost type, microbial population etc. (Scheuerell & Mahaffee, 2002). Most importantly, our understanding of the exact disease suppressive mechanisms is very limited. This limited knowledge has severally hampered our ability to exploit compost tea for disease management more consistently. Further research is needed to understand the control mechanisms before effective as well as consistent disease control can be

achieved with compost tea. It was claimed that application of compost tea with an adjuvant would improve the coverage of microbial population of the host surface. However, in this study inclusion of adjuvant did not improve disease control. From the current data, we conclude that compost tea as we used in this study might not contain appropriate microbial populations at sufficient high concentrations. However, unless we know the identity of these populations, disease control based on compost tea is more of an art than science.

Of these products tested, Milsana is known to induce resistance to powdery mildew on cucumber (Wurms *et al.*, 1999; Fofana *et al.*, 2002; Petsikos-Panayotarou *et al.*, 2002). Here we have also shown that it has some effects in controlling apple powdery mildew; this partial effectiveness of Milsana against powdery mildew was also observed on rose (Pasini *et al.*, 1997)(Pasini et al., 1997). However, on its own it is unlikely to manage powdery mildew effectively in the UK.

Many research studies have indicated various bicarbonate salts can be used to suppress disease development, such as pepper powdery mildew, postharvest pepper rot (Fallik *et al.*, 1997a; Fallik *et al.*, 1997b), anthracnose rot in papaya (Gamagae *et al.*, 2003), citrus foliar diseases (McGovern *et al.*, 2003), botrytis (Palmer *et al.*, 1997) and cucumber powdery mildew (Reuveni *et al.*, 1996). We did not include any bicarbonate salts in the present study because these were being tested in other trials against apple mildew. Results from those trials were also very disappointing. Interestingly, in a filed plot at East Malling application of potassium bicarbonate has failed to control powdery mildew satisfactorily on strawberry. In addition, a few studies also indicated that phosphate salts can also control some diseases (Reuveni *et al.*, 1996); but it did not have any effects on apple powdery mildew as shown in this study. $Ca(OH)_2$ did control mildew satisfactorily in the glasshouse trials; however, the treated leaves became white, which does not convey the ‘green’ essence of organic production well; for this reason, we did not test this product any further.

In the UK, environmental conditions are very conducive to scab and mildew development and furthermore in our testing experiments disease pressure (inoculum) was very high. In general it is expected that these ‘natural’ products are not as effective as synthetic fungicides in controlling diseases. Therefore, the efficacy of these products might be even worse in areas where disease risks are high, as in the UK. We conclude that for a successful organic apple production in the UK conditions it is essential to plant cultivars that are resistant to scab and preferably to powdery mildew as well.

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Objective 4: To determine and optimise the efficacy of six organically acceptable foliar spray treatments for control of rosy apple aphid.

SUMMARY (OBJECTIVE 4, FINAL REPORT)

In two small plots replicated experiments, the efficacy of foliar sprays of *Quassia amara* extract, or the entomopathogenic fungus *Beauveria bassiana*, or Neem extract, Garlic extract, or of 2 novel botanical insecticides or of potassium soap or rotenone were evaluated against established rosy apple aphid colonies in spring. None of the products showed aphicidal properties in this situation.

A series of 8 large scale replicated orchard experiments evaluated control of rosy apple aphid by autumn applications of aphicides. The trials showed that control of the aphid in the autumn can be highly effective with conventional insecticides and moderately effective with the organically permitted insecticide pyrethrum.. Of the products tested, the conventional insecticides pirimicarb + cypermethrin or pirimicarb alone were the most effective. Programmes of 3 sprays of these insecticides between late September and the end of October gave virtually complete control of rosy apple aphid. In one experiment, a single spray of pirimicarb + cypermethrin on 11 October 2001 gave 93% control whereas single sprays on 27 September or 25 October 2001 gave 34% and 70% control respectively, indicating early-mid October as being the optimum time of application in that year.

Of the organically acceptable aphicides tested, pyrethrum (Py Insect Killer) was the most effective, programmes of 2-3 sprays in October giving 50-80% control. None of the other organically acceptable treatments tested in the autumn application experiments, potassium soap (Savona), rotenone (Derris), garlic extract (Envirepel), Kaolin (Surround), neem extract (active ingredient Azadirachtin) (Neemazal TS) or natural plant extracts (Majestik) were sufficiently efficacious to provide a worthwhile degree of control of rosy apple aphid when applied in the autumn. Rotenone (Derris) and potassium soap were not effective as multiple sprays in admixture.

INTRODUCTION (OBJECTIVE 4, FINAL REPORT)

The rosy apple aphid *Dysaphis plantaginea* (Passerini) is a key pest in western European apple orchards and is one of the most troublesome pests in organic apple production. The common strategy to control this aphid pest in conventional apple production is application of an aphicide just before flowering, very often followed by a second application after flowering or in early summer. Systemic aphicides are preferred as they can control aphids protected in curled foliage. In organic apple production, D. *plantaginea* is controlled by sprays of neem extract, carefully timed against fundatrices in spring (e.g. Hohn et al. 1996; Schulz. et al, 1997; Wyss, 1998; Losch, et al, 1998, 1999). Neem extract is not currently approved for use in the UK and spring sprays of potassium soap, which is permitted for use in organic production in the UK, are sometimes used by UK organic apple growers but efficacy is variable and often poor.

In autumn, winged male and female sexuparae migrate from the secondary host, plantain, to the primary host apple. The possibility of controlling rosy apple aphid in the autumn was recognised by Theobald in 1921. He conducted tests spraying hot

lime and concluded that 'much better results can be obtained in the autumn to kill males and ovipositing females which occur in great numbers under the flat leaves. Soft soap (10 lb. to 100 gals. Water) is as effectual for this purpose as paraffin emulsion' (Theobald, 1922). Theobald also recognised the importance of controlling the aphid before it could protect itself in the curled foliage.

In other European countries, rosy apple aphid is controlled in organic apple production by sprays of neem extract (NeemAZal TS, Trifolio Gmbh), targeted against the fundatrices in early spring. (e.g. Hohn et al., 1996; Kienzle et al., 1997;Vogt et al., 1997; Zuber, 1995). Timing of application is critical. However, neem extract is not available or approved for use on fruit crops in the UK.

Objective 4 of this project was to evaluate six foliar spray treatments for control of rosy apple aphid with a view to identifying an effective, organically-acceptable foliar spray treatment for control of the pest. Initially, the aim was to evaluate the efficacy of a range of products applied shortly after hatching of overwintered eggs at the green cluster growth stage and when colonies have developed after blossom. However, two initial experiments showed that it was difficult to get an acceptable standard of control at this time of application. A series of 8 large scale field experiments were then conducted to identify treatments that were effective when applied against aphids in the autumn. The results of these spring and autumn rosy apple aphid control experiments are reported here.

METHODS AND MATERIALS (OBJECTIVE 4, FINAL REPORT)

Sites

A total of 10 replicated experiments were done between 2000 and 2005 (Table 4.1). In two of the experiments, spray applications were made in the spring to small replicated orchard plots (spring experiment 1) or potted trees in a glasshouse (spring experiment 2). In the 8 other experiments, sprays were applied to large, well separated, replicated plots in commercial apple orchards at various times in the autumn against gynoparae, males and oviparae using the grower's axial fan airblast sprayer. The orchards were of the variety Bramley except autumn experiment 5 where the varieties were Discovery and Egremont Russet. These varieties are known to be highly susceptible to rosy apple aphid.

Treatments

Fourteen different materials were tested as foliar sprays in the various experiments (Table 4.2).

Spring experiments: The two spring experiments evaluated the same range of products (extracts of *Quassia amara*, neem, garlic and *Calceolaria*, potassium soap, rotenone, a commercial formulation of a hemipteran strain of the entomopathogenic fungus *Beauveria bassiana* and an admixture of the conventional insecticides pirimicarb and cypermethrin as a positive control) (Tables 4.3 & 4.4). Sprays were applied with a motirised air-assisted knapsack sprayer.

Autumn experiments: In the first two autumn experiments, programmes of 4 (experiment 1) or 3 (experiment 2) sprays of potassium soap, rotenone, garlic extract

or pirimicarb + cypermethrin were applied to cover the aphid migration period from late September to end of October/early November (Tables 4.6 & 4.7). Autumn experiments 3, 5 and 8 explored different times of application of different products and mixes (Tables 4.8, 4.10 & 4.13). The aim was to determine the most effective time to spray during the autumn migration period. Autumn experiments 6 and 7 evaluated the efficacy of multiple applications of different products (Tables 4.11 & 4.12). Sprays were applied with the grower's axial fan airblast sprayers.

Experiment design

Randomised complete block experimental designs with 5 (spring experiment 1) or 4 (all other experiments) replicates were used throughout. In spring experiment 1, each plots consisted of two adjacent semi-dwarf Bramley trees. In spring experiment 2, each plot was a single potted 2 year old, well feathered Bramley tree, artificially infested and held in a glasshouse compartment. Large, well spaced, plots consisting of at least 20 trees and guarded by several unsprayed guard rows, were used for the autumn application experiments.

Assessments

Assessment methods and sample sizes were adjusted according to the experiment design and aphid population density.

For spring experiment 1, assessments were done on two occasions, on 1 June, 14 June 2000. For each assessment, ten aphid colonies in the central area of each two-tree plot were assessed for the number of infested leaves, number of live aphids per leaf and the number of aphid predators per colony. A beat sample consisting of 4 beats per plot over a standard beating tray was done to assess populations of aphid predators. Sample colonies were from the untreated plots and from those treated with *Beauveria bassiana* were examined in the laboratory at HRI Wellesbourne by an insect pathologist and the species present were identified. In spring experiment 2, assessments of aphid numbers were done 24 hours and 6 days post spraying. Five infested leaves per tree were examined and the number or dead and live aphids on each leaf were counted and recorded.

For autumn experiment 1, assessment of the density of colonies of rosy apple that developed in spring was done on 26 April 2001 at the green cluster to pink bud growth stage and repeated at full bloom on 14 May 2001. For each assessment, the number of rosy apple aphid colonies that develop on each of 20 trees per plot was counted.

For autumn experiment 2, assessment of the density of colonies of rosy apple that developed in spring was done on 25-26 April 2002 at the full bloom growth stage. The number of leaves infested and the number damaged by rosy apple aphid colonies on each of 20 trees per plot was counted. In addition, 5 blossom trusses on each tree were closely examined for other pests including apple grass aphid, rosy leaf curling aphid, caterpillar damage, winter and tortrix moth caterpillars. Presence or absence of each pest in each truss was recorded.

For autumn experiment 3, assessment of the density of colonies of rosy apple aphid was done on each plot on 25 April at the full bloom growth stage. The number of leaves damaged and the number infested with rosy apple aphid colonies were counted on each of 20 trees per plot.

For autumn experiments 4 and 5, on 21-25 April 2003 at the pink bud to early bloom growth stage, the number of rosy apple aphid and the number of apple grass aphid colonies were counted on the central 20 trees in each plot, 10 of each variety, in each plot in experiment 5.

For autumn experiments 6 and 7, there was a very large return autumn migration of rosy apple aphid in 2003. This made it possible to assess the populations of migrants on the foliage for the first time. In the sixth experiment, one shoot on each of the 20 trees in each plot was carefully examined for rosy apple aphid gynoparae and males. Other species (not identified) were also counted. On 13-16 April 2004, at the green cluster growth stage when aphids had emerged in spring, an assessment of the density of colonies of rosy apple was done at the green cluster to pink bud growth stage. For the assessment, the number of rosy apple and other aphid species that were present on five clusters on each of 20 trees per plot were counted.

For autumn experiment 8, assessments of the numbers of aphids were carried out on 18 April 2005, at the late green cluster – pink bud growth stage. In total, 160 trees of each treatment were examined and records were taken of the number of rosy apple aphid and apple grass aphid colonies found.

Statistical analysis

Where appropriate, analysis of variance was conducted on the data, with square root or $\log_{10}(n+1)$ transformation where necessary to stabilise variances.

RESULTS (OBJECTIVE 4, FINAL REPORT)

Spring experiment1

None of the treatments tested, including the rotenone or potassium soap standards, reduced the percentage colonies with live aphids, the percentage leaves with live aphids or the mean number of aphids per colony compared to the untreated control (Table 4.3). Populations on all plots declined markedly between the first and second assessments. This was probably due mainly to the effects of weather, which was very wet during this period. A wide range of predatory insects were found in the aphid colonies and or in the beat samples including ladybird adults and larvae, earwigs, syrphid larvae, lacewing larvae, spiders, predatory midge larvae, mirids and anthocorids (Table 4.4). Numbers were somewhat erratic and were unsuitable for analysis of variance. Syrphid larvae, lacewing larvae and ladybirds predominated but numbers generally declined by the second assessment, mainly because aphid populations, their food source, were declining. None of the treatments tested appeared to greatly reduce predator populations markedly though numbers of individuals were too small and erratic to determine subtle effects of the treatments on predators.

Spring experiment 2

The pirimicarb + cypermethrin treatment was highly effective reducing the numbers of live aphids to near zero by 24 hours after treatment and maintaining them at that level for at least 6 days (Table 4.5). Of the other treatments tested, only potassium soap significantly reduced live aphid numbers compared to the control, by approximately 80% by 24 hours after treatment. However, the effects of the potassium

soap treatment were short lived and numbers of aphids on the trees treated with the product increased rapidly thereafter, so that they were only approximately 60% lower than the control by 6 days after treatment. None of the treatments tested show good efficacy as spring sprays.

Autumn experiment 1

The weather in autumn 2000 was very wet. There were very few days in September suitable for aphid migration and subsequent population development on apple. Very few rosy apple aphid colonies developed in spring, even on the untreated control plots (Table 4.6). Numbers declined somewhat between the first and the second assessment. However, the greatest number of colonies (56 on a total of 100 trees) developed on the untreated control plots, though numbers varied greatly between replicates (minimum 1, maximum 28 per 20 trees on 26 April). In contrast, no colonies developed on the plots that had received the programme of sprays of pirimicarb + cypermethrin. This indicates that this treatment was quite effective. Potassium soap, rotenone or garlic extract did not appear to be as effective. However, it is not possible to reach firm conclusions about the relative effectiveness of the treatments because populations were too small. Results from the first and second assessments were similar.

Autumn experiment 2

The programme of 3 autumn sprays of pirimicarb + cypermethrin was nearly 100% effective (Table 4.7). It reduced the numbers of leaves per 20 trees damaged on 25 April the following spring to zero and the numbers of infested leaves to near zero. Only one live aphid was found on the 80 trees that received this treatment (this leaf was not showing damage symptoms). There were no statistically significant treatment effects in the analysis of variance of the other treatments. The garlic treatment had virtually the same numbers of damaged and infested leaves as the control. The rotenone and potassium soap treatments had approximately 50% of the numbers of damaged and infested leaves. This result indicated that none of the 3 organically acceptable treatments tested, potassium soap (Savona), rotenone (Derris) or garlic extract (Envirepel) are sufficiently efficacious to provide an adequate degree of control of rosy apple aphid when applied in the autumn.

Autumn experiment 3

As in the second autumn application experiment, the programme of three sprays of pirimicarb + cypermethrin was 100% effective (Table 4.8). The latter two timings of single spray treatments of this insecticide mixture both reduced the numbers of damaged and infested leaves significantly compared to the control, and the first spray timing nearly so. The second timing (11 Oct) was clearly the most effective followed by the third (25 October) timing with the first application least effective, though differences between the individual timings were not statistically significant. The programme of 3 sprays of potassium soap + rotenone did not significantly reduce the numbers of aphids nor did any of the single treatments.

Autumn experiment 4

The very low numbers of rosy apple aphid and apple grass aphid that developed in spring 2003, even on the untreated control plots, meant that it was difficult to draw any firm conclusions form the data. However, the pirimicarb treatment did appear to give complete control of the very low populations of aphids that occurred (Table 4.9).

Autumn experiment 5

Numbers of rosy apple aphid were so small that no conclusions about the efficacy of the treatments could be drawn from the data. However, both pyrethrum and the natural plant products (Majestik) treatments did reduce apple grass aphid numbers compared to the untreated control (Table 4.10).

Autumn experiment 6

There was a great deal of variation in the numbers of autumn migrants and it was not possible to draw firm conclusions about the effects of the treatments on the numbers recorded in the autumn (Table 4.11). Note this assessment was done after the first autumn application but before the second. However, the data do suggest that the pyrethrum, kaolin and azadirachtin treatments were not having any significant effect and that pirimicarb possibly was. However, at the spring assessments on 15 April 2004, the analysis of variance of the square root transformed data revealed highly significant treatment effects ($P < 0.001$). The pyrethrum treatment reduced aphid numbers by 80%, the pirimicarb treatment by 96%.

Autumn experiment 7

Analysis of variance of the square root transformed rosy apple aphid data revealed highly significant ($p = 0.003$) treatment effects (Table 4.12). The pyrethrum, pirimicarb and azadirachtin treatments reduced number of aphids by 80%, 92% and 70% respectively compared to the untreated control. For natural plant products and kaolin treatments, the reduction was not significant statistically. All the treatments except the natural plant products greatly reduced numbers of apple grass aphid. The pirimicarb and azadirachtin treatments were particularly effective but the pyrethrum and kaolin treatments also significantly reduced numbers by 65% and 78% respectively.

Autumn experiment 8

Numbers of aphids that occurred in spring 2005 were extremely small and somewhat variable. Analysis of variance of the $\log_{10}(n+1)$ rosy apple aphid colony counts per plot showed that the single pirimicarb spray in mid October 2004 reduced numbers of aphids by 94% compared to the untreated ($p=0.001$) (Table 4.13). None of the individual pyrethrum treatments reduced numbers of rosy apple aphid colonies significantly compared to the untreated though the mean values were 52-64% of the control.

DISCUSSION (OBJECTIVE 4, FINAL REPORT)

Several other research groups in Europe investigated autumn control of rosy apple aphid at the time the work reported here was done. In Belgium from 1997-2001, Romet (2004) investigated the effect of defoliation of trees and the optimum date of defoliation. The aim was to remove the foliage before the arrival of gynoparae or before ovipositition on bark by oviparae However, no significant differences were observed between trees defoliated on 22 October or 5 November, or not defoliated. This is not surprising because aphid migration data indicates that the defoliation was probably done too late (see below). However, apple varieties with a long cycle (retaining their leaves late in the autumn), such as Granny Smith and Pink Lady, were found to be more susceptible to this pest. Treatment of trees with clay kaolin (Argirec B34 or Surround) resulted in a decrease in aphid populations. Hoehn et al. (2003) also investigated the impact of artificial defoliation and/or an aphicide treatment in autumn on the aphid population in the following year in an experiment in an apple orchard in Switzerland in 2000-2001. In 4 of 8 plots, the trees were completely defoliated by hand at the end of September 2000. At the same time, the aphicide triazamate was sprayed on half of the orchard (2 defoliated plots and 2 plots without defoliation). Aphid populations were assessed 3 times in 2001 (before and after flowering and in June, respectively). Defoliation controlled rosy apple aphid and apple-grass aphid (*Rhopalosiphum. insertum*) successfully. Green apple aphid (*Aphis pomi*) was not significantly reduced, possibly because since this species has the ability to colonize apple in spring and summer. Aphicide application in autumn had no significant effect.

Wyss and Daniel (2004) also investigated autumn treatment with pyrethum or kaolin (Surround) in 1-year field experiments in Switzerland. Single and multiple applications of pyrethrin and kaolin were tested at different dates after apple harvest in autumn 2002 when sexuals were present. Repeated applications of Surround in autumn significantly reduced the number of females in autumn and, consequently, the number of hatched fundatrices in spring. Single kaolin treatments were less effective. Unexpectedly, neither single nor multiple applications of the pyrethrum had a knock-down effect on females in autumn. However, pyrethrin significantly reduced the number of hatched fundatrices in spring. Neither pesticide completely controlled the rosy apple aphid but Wyss and Daniel concluded that with a more detailed analysis of factors influencing the efficacy of autumn treatments a new approach to control this pest could be achieved.

Helsen (2001) and Helsen and Simonse (2002) investigated the effects of spray timing of the conventional insecticides imidacloprid (Admire), pirimicarb or an experimental material ‘Middel Z’ or of the organically permitted insecticide potassium soap (Savona) in the autumn. In a first experiment, a single application of imidacloprid on 9 October 2000 gave 98% control of rosy apple aphid the following spring. In a further experiment the following year, applications were made at various timings in October 2001. Imidacloprid or pirimicarb on 12 October or ‘Middel Z’ applied on 5 October gave very good (>90%) control. Imidacloprid on 26 October or Middel Z on 11 October were less effective. A single spray of potassium soap on 5 October or 2 sprays on 5 and 12 October, respectively, gave <30% control. In a further experiment, a spray of imidacloprid on the 11 October 2001 gave 100% control and a spray of pirimicarb on 12 October gave 83% control. Helsen and Simonse (2002) also studied the production of winged rosy apple aphid migrants on plantain held in cages in semi-field conditions. Gynoparae started to migrate at the end of September. The migration reached its peak on about 5 October and ended

about 13 October. The migration of males started about 3 weeks later on 13 October and ended at the end of October.

The results of the work reported here broadly concur with the above findings of other researchers, but differ in a number of important respects. Overall, this work indicates that control of rosy apple aphid with aphicides that are permitted in organic production is difficult in spring and that application in the autumn may be more effective. However, best control form autumn application is obtained with conventional insecticides. Persistent aphicides, like imidacloprid, are particularly effective, but one or two sprays of less persistent materials such as pirimicarb can give a high degree of control. The results collectively also indicate that, if a single application is to be applied, then the best time is roughly at the end of the first week in October. Aphid migration data from the work of Helsen and Simone (2002) suggest that application at this time coincides with the peak of the migration of gynoparae and the start of the migration of males. A histograms of the average numbers of rosy apple aphid captured per week in the Rothamsted Insect Survey suction trap at Wye in Kent over a 10 year period from 1995-2004 inclusive (Figure 4.1) shows that the migration of gynoparae starts in week 38 (mid September) and ends in week 41 (mid October) (R Harrington pers. com.). Unfortunately, identification of aphids in the genus *Dysaphis* to species is difficult and the suction trap data is rather scanty and contains numerous zero values. A histogram of the suction trap catches of all *Dysaphis* species (Figure 4.1) shows a broader period of the migration with the migration of males starting 2-3 weeks after the gynoparae. The flight of rosy apple aphid males was monitored with sex pheromone traps at East Malling Research in 2003 and 2004. In 2003, traps were deployed on 9 October and the first catch was recorded on 14 October 2003. The peak catch occurred on 28 October but the flight continued till 12 November when recording ceased. In 2004, the traps were deployed on 15 October 2004 and caught males immediately indicating the flight has already started. The peak was reached on 5-8 November with the last catch on 25 November 2004 (J Fitzgerald, pers. Com.). This data broadly indicates that the male flight begins in mid-October. It is likely that the time of migration and its size and duration differ considerably from year to year. However, application of aphicides which only have a short persistence, such as those permitted for use in organic production, in early to mid-October would be most likely to control the maximum proportion of gynoparae and oviparae before the arrival of males and the onset of oviposition. This work shows that one spray of an effective aphidicide of short persistence such as pirimicarb at this time can give a high degree of control. Even better results might be expected with a more persistent aphicide such as imidacloprid, which concurs with the findings of Helsen (2001) and Helsen and Simonse (2002). A simple way of monitoring the migration would be valuable and assist in the optimal timing of autumn sprays.

This work shows that sprays of a wide range of organically permitted materials claimed or considered to have aphicidal properties including kaolin (Surround), potassium soap (Savona), garlic extract, rotentone (Derris), neem extract (NeemAZal TS) or natural plant extracts (Majestik) are at best of limited effectiveness, even as multiple applications. Of the organically permitted materials evaluated for autumn control, pyrethrum was the most effective, but results were somewhat variable. This work shows that it is necessary to apply several sprays of pyrethrum to reliably get a reasonably high standard of control, presumably because the persistence of pyrethrum is very short. As pyrethrum is purely a contact acting insecticide, it can be envisaged that best results would be achieved with high volume sprays designed to directly intercept the maximum proportion of the population

CONCLUSIONS (OBJECTIVE 4, FINAL REPORT)

- Sprays of *Quassia amara* extract, or the entomopathogenic fungus *Beauveria bassiana*, neem extract (azadirachtin), Garlic extract, of 2 novel botanical insecticides or of the standards potassium soap or rotenone did not control established rosy apple aphid colonies in spring. None of the products showed aphicidal properties in this situation.
- Control of rosy apple aphid by autumn applications of aphicides can be highly effective. Of the products tested, the conventional insecticides pirimicarb + cypermethrin or pirimicarb alone were the most effective. Programmes of 3 sprays of these insecticides between late September and the end of October gave virtually complete control of rosy apple aphid.
- In one experiment, a single spray of pirimicarb + cypermethrin on 11 October 2001 gave 93% control whereas single sprays on 27 September or 25 October 2001 gave 34% and 70% control respectively, indicating early-mid October as being the optimum time of application in that year.
- Of the organically acceptable aphicides tested, pyrethrum (Py Insect Killer) was the most effective, programmes of 2-3 sprays in October giving 50-80% control.
- None of the other organically acceptable treatments tested in the autumn application experiments, potassium soap (Savona), rotenone (Derris), garlic extract (Envirepel), Kaolin (Surround), azadirachtin (Neemazal TS), natural plant extracts (Majestic) were sufficiently efficacious to provide a worthwhile degree of control of rosy apple aphid when applied in the autumn. Rotenone (Derris) and potassium soap were not effective as multiple sprays in admixture.

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Table 4.1. List of experiments, location and season of spray application.

Experiment	Location	Time of treatment application
Spring 1	DM152 Bramley orchard, East Malling Research, Kent	Spring 2000
Spring 2	Potted Bramley trees in the glasshouse at East Malling Research, Kent	Spring 2002
Autumn 1	Parsonage Bramley orchard, Poultry farm, Marden	Autumn 2000
Autumn 2	Parsonage Bramley orchard, Poultry farm, Marden	Autumn 2001
Autumn 3	Yopps Bramley Orchard, Sheet Hill, Yopps Green, Kent	Autumn 2001
Autumn 4	Parsonage Bramley Orchard, Poultry Farm, Marden	Autumn 2002
Autumn 5	Bean field organic dessert orchard, Hartley Lands Farm, Cranbrook, Kent	Autumn 2002
Autumn 6	Parsonage Bramley orchard, Poultry farm, Marden, Kent	Autumn 2003
Autumn 7	No.10 M26 Bramley orchard at Broadwater farm, West Malling, Kent	Autumn 2003
Autumn 8	No. 10, M26 Bramley orchard at Broadwater farm, West Malling, Kent	Autumn 2004

Table 4.2. Active substances and agents, products and doses evaluated

Active substance or agent	Product	Dose product (l/ha)
Azadirachtin	NeemAzal TS	3l
Beauveria bassiana	Botanigard ES	5 l
Calceolaria extract 1	BTG504	2 l
Calceolaria extract 2	BTG505	2 l
Cypermethrin	Toppel 10	280ml
Garlic extract	Envirepel	1 l
Kaolin	Surround	50 kg
Natural plant extracts	Majestik	25 l
Neem extract	Neemazal TS	6 l
Pirimicarb	Aphox	560g
Potassium soap	Savona	20-40 l*
Pyrethrum	Py Insect Killer	10 l
Quassia amara extract	Bittrosan	4 l
Rotenone	Derris	2.5 l

*Applied at 2% concentration so dose rate per ha depended on the spray volume

Table 4.3. Treatments and results of spring experiment 1. The 1st spray was applied in a volume of 800 l/ha on 25 May and second spray on 7 June 2000.

Treat no. and active ingredient	% colonies with live aphids		% leaves with live aphids		Mean no. aphids/colony	
	1st June*	14th June†	1st June*	14th June†	1st June*	14th June†
1. *Quassia amara* extract	89	44	67.9	22.3	92	20
2. *Beauveria bassiana*	98	52	75.0	28.0	120	32
3. Neem extract	92	38	70.3	21.2	100	16
4. Garlic extract	92	42	66.2	22.6	61	15
5. plant extract 1	92	50	65.2	26.4	79	29
6. plant extract 2	92	22	71.1	12.5	107	11
7. Potassium soap	89	50	73.7	43.7	93	72
8. Rotenone	92	28	61.1	16.7	72	11
9. Untreated	88	28	70.6	22.0	93	23
SED (30df)	6.3	11.7	9.21	9.53	36.2	19.8

* 7 days after first spray † 7 days after second spray

Table 4.4. Mean numbers of predatory insects and spiders found per plot in experiment 1.

Treatment	Ladybird larvae	Ladybird adults	Earwigs	Syrphids	Lacewing	Spider	Midge	Anthocorids
First assessment on 1 June 2000, 7 days after the first spray								
Quassia	0.4	0.4	0.4	0.8	4.6	1.6	2.6	0.8
Beauveria	0.0	0.2	0.4	2.6	4.0	1.8	0.4	1.6
Neem	0.2	0.4	1.4	4.6	5.0	0.8	0.2	0.8
Garlic	0.3	0.3	1.8	3.8	5.3	0.8	0.5	0.3
'coded' 4	0.6	0.4	2.2	1.6	7.2	0.4	0.2	0
'coded' 5	0.4	0.2	1.4	5.2	4.2	1.8	0.0	2.6
Savona	0.5	0.0	0.8	1.8	6.8	1.5	3.8	0.3
Derris	0.2	0.4	1.0	2.4	4.2	0.8	0.6	0.6
Control	0.2	1.2	2.2	1.0	5.0	1.2	0.2	0.8
Second assessment on 14 June 2000, 7 days after the second spray								
Quassia	3.4	0	0.4	0	0.4	0	0	0
Beauveria	2.4	0	0	0.4	0.6	0	0.8	0
Neem	1.0	0	0.4	0	0	0	0.4	0
Garlic	3.2	0	1.0	0.4	0	0	0	0
'coded' 4	2.4	0	1.2	0	0	0	0	0
'coded' 5	1.6	0.2	0.4	0.2	0	0	0	0
Savona	4.0	0	1.8	0	1.6	0	0	0
Derris	1.6	0	2.4	0.6	0	0	0	0
Control	1.2	0	1.8	0.4	0.6	0	0	0

Table4.5. Treatments and results of spring experiment 2. Sprays applied in 1000 l /ha on 20 March 2002 assessments 6 days later.

	Damaged leaves		Infested leaves	
	n	n√	n	n√
1. *Quassia amara* extract	49.6	6.42	93.7	9.29
2. *Beauveria bassiana*	30.7	4.93	28.7	4.89
3. Neem extract	36.7	5.52	34.2	5.48
4. Garlic extract	66.6	7.38	63.3	7.46
5. *Calceolaria* extract 1	45.0	5.95	51.5	6.79
6. *Calceolaria* extract 2	37.3	5.27	34.7	5.74
7. Potassium soap	8.0	1.85	17.5	3.44
8. Rotenone	52.1	6.04	52.3	6.98
9. Cypermethrin + pirimicarb	0.1	0*	0	0*
10. Untreated-	37.5	4.96	40.7	5.83
Fprob		<0.001		<0.001
SED (25 df)		0.995		0.756

* Treatment 9 not included in analyses of variance. SED values cannot be used for comparisons with treatment 9.

Table 4.6. Treatments and results of autumn experiment 1. Sprays applied in 1000l water/ha on 22 Sept, 2 Oct, 17 Oct, 24 Oct and 1 Nov 2000.

Treat no. and active ingredient.	Total number of aphid colonies recorded in spring 2001*	
	26th April (green cluster)	14th May (full bloom)
1. Potassium soap	10	12
2. Rotenone	4	6
3. Garlic extract	19	6
4. Pirimicarb + cypermethrin	0	0
4. Untreated-	28	11

* Data unsuitable for analysis of variance

Table 4.7. Treatments and results of autumn experiment 2. Sprays applied in 1000 l /ha on 27 Sept, 11 Oct and 25 Oct 2001.

Treat no. and active ingredient.	Mean number (and mean square root number) of aphid damaged or infested leaves per 20 trees on 25 April 2002 (full bloom).			
	Damaged		Infested	
	n	√ n	n	√ n
1. Potassium soap	15.5	3.78	13.8	3.66
2. Rotenone	13.0	3.33	13.8	3.44
3. Garlic extract	30.0	5.23	21.0	4.29
4. Pirimicarb + cypermethrin	0	0 *	0.3	*
5. Untreated	31.5	5.39	30.0	5.13
Fprob*		0.18		0.359
SED (9df)		1.02		0.972

* Treatment 4 not included in analysis of variance. SED value cannot be used for comparisons with treatment 4.

Table 4.8. Treatments and results of autumn experiment 3. Sprays applied in 500 l /ha on 27 Sept, 11 Oct and 25 Oct 2001, assessment on 22 April 2002 at full bloom.

Treat no. and spray dates		Damaged leaves/20 trees		Infested leaves/20 trees	
		n	√n	n	√n
1. Potassium soap + rotenone	27 Sep	30.0	5.16	14.8	3.53
2.	11 Oct	30.5	4.92	13.0	3.37
3.	25 Oct	15.5	3.66	8.3	2.79
4.	All 3 dates	20.5	4.38	9.8	3.08
5. Pirimicarb + cypermethrin	27 Sep	15.0	3.45	7.0	2.26
6.	11 Oct	1.5	0.81	1.5	0.81
7.	25 Oct	7.0	2.28	3.8	1.65
8.	All 3 dates	0	0*	0	0*
9. Untreated	-	23.0	4.60	10.5	3.04
	Fprob*		<0.001		0.008
	SED (25df)* - comparisons with control		0.601		0.612
	- other comparisons		0.693		0.706

* Treatment 8 not included in analyses of variance. SED values cannot be used for comparisons with treatment 8.

Table 4.9. Treatments and results of autumn experiment 4. Sprays applied in 1000 l /ha on 27 Sept, 18 Oct and 28 Oct 2002, assessment on 21 April 2003 at full bloom

a.i.	Total number of rosy apple aphid colonies	Total number of green apple aphid colonies
1. Natural plant extracts	12	11
2. Pyrethrum	6	1
3. Kaolin	12	8
4. Pirimicarb	0	0
5. Untreated	13	4

Table 4.10. Treatments and results of autumn experiment 5. Sprays applied in 1000 l /ha, assessment on 24-25 April 2003 at full bloom.

Treatment and product	Dates of application (2002)	Total rosy apple aphid colonies colonies		Total apple grass aphid colonies	
		Disc†	Egre‡	Disc†	Egre‡
1. Pyrethrum 10 g/l	*7 Oct*	*1*	*0*	*27*	*18*
2.	17 Oct	0	0	46	13
3.	29 Oct	1	1	9	11
4.	All 3 dates	0	0	14	6
5. Natural plant products	*7 Oct*	*2*	*0*	*55*	*3*
6.	17 Oct	4	1	37	9
7.	29 Oct	2	7	97	40
8.	All 3 dates	0	1	33	17
9. Untreated	-	6	0	100	38

Note: Data not suitable for statistical analysis †Discovery ‡Egremont Russet

Table 4.11. Treatments and results of autumn experiment 6. Sprays applied in 1000 l /ha on 9 Oct 2003 and 21 Oct 2003, assessment on 24-25 April 2003 at full bloom.

Treat no. and active ingredient.	Total aphids / 100 shoots (20 Oct 2003)	Mean no. aphids/100 clusters (15 April 2004)	
		n	√n
1. Natural plant extracts	5	21.0	4.5
2. Pyrethrum	21	4.5	2.09
3. Kaolin	20	25.5	4.93
4. Pirimicarb	1	0.8	0.60
5. Neem extract	31	25.2	4.66
6. Untreated	5	22.8	4.74
		Fprob	<0.001
		SED (15 df)	0.745

Table 4.12. Treatments and results of autumn experiment 7. Sprays applied in 500 l /ha on 8 Oct 2003 and 22 Oct 2003, assessment on 14 April 2004 at green cluster.

Treat no. and active ingredient.	Mean number of aphid colonies per 100 clusters (14th April 2004)			
	Rosy apple aphid		Apple grass aphid	
	n	√n	n	√n†
1. Natural plant extracts	27.0	4.89	20.8	4.41
2. Pyrethrum	10.3	2.66	7.7	2.70
3. Kaolin	28.0	4.67	4.7	2.10
4. Pirimicarb	4.0	1.50	0	(0)
5. Azadirachtin	15.8	3.73	0.7	(0.43)
6. Untreated	52.5	6.18	21.8	4.48
Fprob		0.003		<0.051
SED (15 df)		0.965		
SED (9df)				0.875

†Treatment 4 excluded from analysis of variance

Table 4.13. Treatments and results of autumn experiment 8. Sprays applied in 500 l /ha on 1 Oct and 8 Oct 2004, assessment on 18 April 2004 at green cluster.

Treat no. and active ingredient.	Spray timing (2004)	Total number of aphid colonies/160 trees on 18 April 2005		
		Rosy apple aphid		Apple grass aphid
		n	$Log_{10}(n+1)$	n
1. Pyrethrum	1 Oct	15.0	1.162b	2.8
2. Pyrethrum	8 Oct	14.0	1.091b	6.0
3. Pyrethrum	1 and 8 Oct	12.2	0.995b	4.0
4. Pirimicarb	Mid Oct	23.5	0.325a	4.0
5. Untreated		1.5	1.362b	4.3
	Fprob		0.001	
	SED (12 df)		0.1839	

Means followed by the same letter do not differ significantly in Duncan's multiple range test (p=0.05)

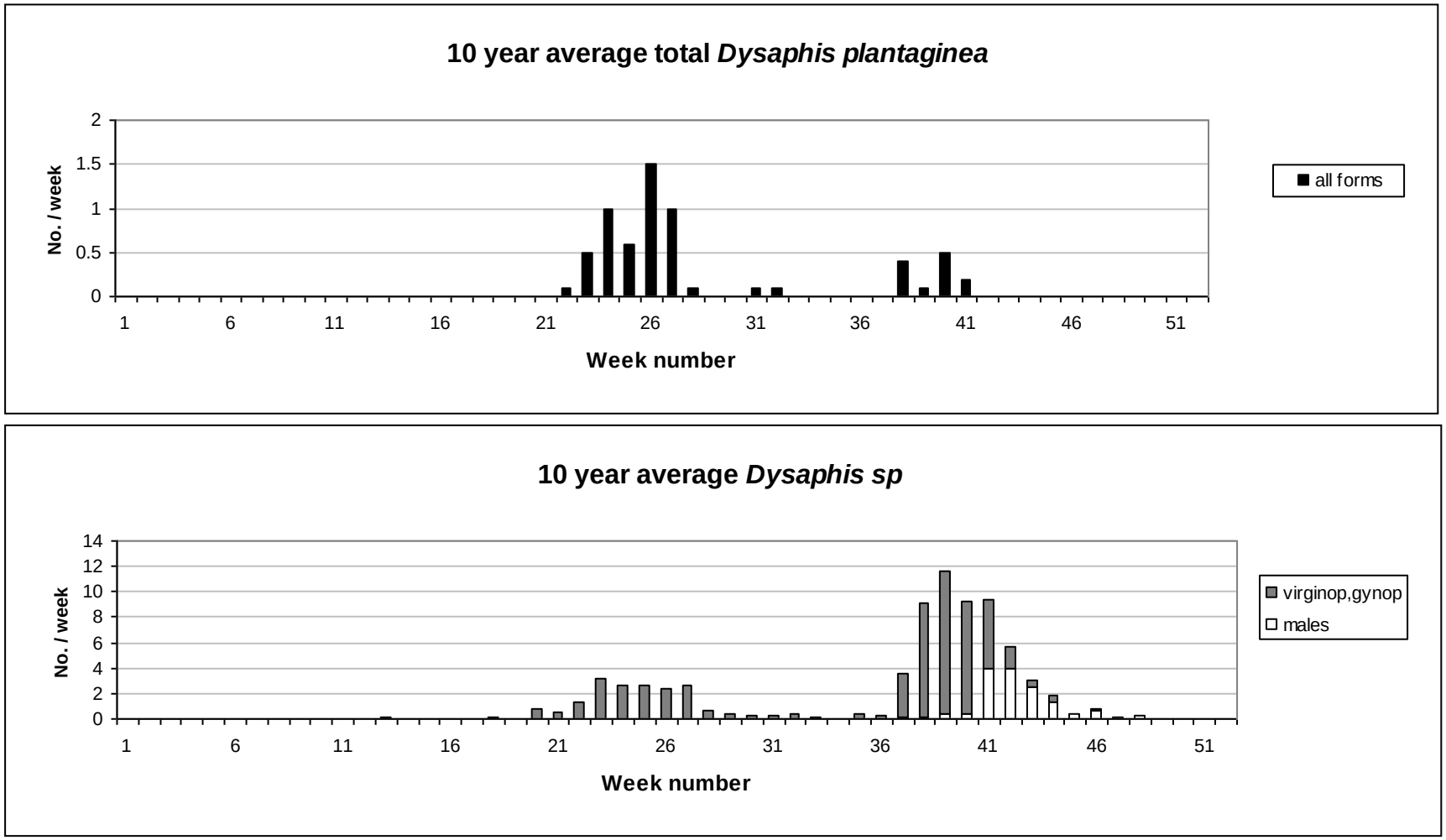

Figure 4.1. 10 year average (1995-2004) catches of rosy apple aphid (*Dysaphis plantaginea*) (above) and of *Dysaphis* sp. (below) in the Rothamsted Insect Survey suction trap at Wye in Kent.

Appendix 1

SENSORY ASSESSMENT OF APPLES – PROFILE TASTING

Name: **Company:** **Date:**

Overall aroma: **Low ----------|----------|----------|---------- High**

Any other flavours: Please describe (e.g; banana, caramel, green/unripe, pear, estery)

Texture:

Firmness: Soft ----------|----------|----------|---------- Hard

Juiciness: Dry ----------|----------|----------|---------- Very juicy

Crispness: Not ----------|----------|----------|---------- Very

Toughness / Chewiness: Not ----------|----------|----------|---------- Very

Flouriness / Mealy: Not ----------|----------|----------|---------- Very

Taste:

Sweetness **Low ----------|----------|----------|---------- High**

Acidity Low ----------|----------|----------|---------- High

Any other additional descriptions:

Shape Poor ----------|----------|----------|---------- Good

Colour Poor ----------|----------|----------|---------- Good

Overall acceptability:

1. Very bad □
2. Bad □
3. Poor □
4. Indifferent □
5. Fair □

6. Pleasant □
7. Good □
8. Very Good □
9. Excellent □

Appendix 2

Organic variety trial VF 216 East Malling

				V (sulphur)								**VI**			
36	4	14	25	15	20	11	17	1	11	6	21	23	8	15
35	4	14	25	15	20	11	17	1	11	6	21	23	8	15
34	4	14	25	15	20	11	17	1	11	6	21	23	8	15
33	23	9	18	2	3	26	27	7	16	24	17	2	22	5
32	23	9	18	2	3	26	27	7	16	24	17	2	22	5
31	23	9	18	2	3	26	27	7	16	24	17	2	22	5
30	1	22	6	24	19	12	7	26	28	18	4	27	14	9
29	1	22	6	24	19	12	7	26	28	18	4	27	14	9
28	1	22	6	24	19	12	7	26	28	18	4	27	14	9
27	16	28	10	5	13	21	8	13	25	19	12	10	20	3
26	16	28	10	5	13	21	8	13	25	19	12	10	20	3
25	16	28	10	5	13	21	8	13	25	19	12	10	20	3
				III							**IV (sulphur)**			
24	21	22	14	17	6	26	24	5	27	26	16	18	2	25
23	21	22	14	17	6	26	24	5	27	26	16	18	2	25
22	21	22	14	17	6	26	24	5	27	26	16	18	2	25
21	12	10	9	25	13	19	2	9	8	3	15	13	6	28
20	12	10	9	25	13	19	2	9	8	3	15	13	6	28
19	12	10	9	25	13	19	2	9	8	3	15	13	6	28
18	3	23	8	15	20	1	5	23	14	4	21	7	19	1
17	3	23	8	15	20	1	5	23	14	4	21	7	19	1
16	3	23	8	15	20	1	5	23	14	4	21	7	19	1
15	18	11	28	16	27	7	4	20	17	12	11	10	24	22
14	18	11	28	16	27	7	4	20	17	12	11	10	24	22
13	18	11	28	16	27	7	4	20	17	12	11	10	24	22
				I (sulphur)								**II**		
12	24	27	14	20	8	15	26	15	1	9	2	5	8	23
11	24	27	14	20	8	15	26	15	1	9	2	5	8	23
10	24	27	14	20	8	15	26	15	1	9	2	5	8	23
9	22	18	10	23	12	28	16	14	11	26	28	24	19	12
8	22	18	10	23	12	28	16	14	11	26	28	24	19	12
7	22	18	10	23	12	28	16	14	11	26	28	24	19	12
6	6	17	1	9	2	4	11	27	10	20	25	21	13	7
5	6	17	1	9	2	4	11	27	10	20	25	21	13	7
4	6	17	1	9	2	4	11	27	10	20	25	21	13	7
3	19	5	25	7	21	3	13	3	4	6	22	18	16	17
2	19	5	25	7	21	3	13	3	4	6	22	18	16	17
1	19	5	25	7	21	3	13	3	4	6	22	18	16	17
TREE ROW	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Planting distances:
Alley width 3.5m. Between trees 1.75m. Row 1 Tree 1 begins in SW corner of plot.
Planting date: December 2001. Trees grafted onto Saturn in March 2001 or March 2002.
Blocks I; IV & V sprayed with sulphur beginning April 2002 onwards.

VARIETIES

1 = Ariwa	8 = Ecolette	15 = Liberty	22 = Red Falstaff (grafted)
2 = Bohemia	9 = Edward VII	16 = Pikant	23 = Resi
3 = Ceeval	10 = Encore	17 = Pilot	24 = Rubinola
4 = D3	11 = Florina	18 = Pinova	25 = Rubinstep
5 = Delorina	12 = Goldrush	19 = Rajka	26 = Santana
6 = Discovery	13 = Howgate W.	20 = Rebella	27 = Topaz
7 = DL 11	14 = Judeline	21 = Red Falstaff	28 = Worcester Pearmain

Appendix 3

Welcome to the Sainsbury's Product Testing Questionnaire

Today we would like you to test two samples of ORGANIC APPLES and tell us which you prefer.

Which are your favourite apple types? Please select all that apply.

- ❑ **Granny Smith**
- ❑ **Cox**
- ❑ **Pink Lady**
- ❑ **Gala**
- ❑ **Braeburn**
- ❑ **Golden Delicious**
- ❑ **Red Declicious**
- ❑ **Russet**

Please try product ?? and then answer the following questions.

Please tell us how you rate the product OVERALL by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

We would now like you to rate the product on several characteristics

[Image 1]

Please tell us how you rate the APPEARANCE by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the SHAPE by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the COLOUR by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the FLAVOUR by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

How do you rate the sweetness?

5 - Far too sweet	*4 - Slightly too sweet*	*3 - Just right*	*2 - Not quite sweet enough*	*1 - Nowhere near sweet enough*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the sourness?

5 - Far too sour	*4 - Slightly too sour*	*3 - Just right*	*2 - Not quite sour enough*	*1 - Nowhere near sour enough*	*No opinion*
❑	❑	❑	❑	❑	❑

Please tell us how you rate the TEXTURE of the product by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

How do you rate the firmness?

5 - Far too soft	*4 - Slightly too soft*	*3 - Just right*	*2 - Slightly too hard*	*1 - Far too hard*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the juiciness?

5 - Far too juicy	*4 - Slightly too juicy*	*3 - Just right*	*2 - Slightly too dry*	*1 - Far too dry*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the crispness?

5 - Far too crisp	*4 - Slightly too crisp*	*3 - Just right*	*2 - Not quite crisp enough*	*1 - Nowhere near crisp enough*	*No opinion*
❑	❑	❑	❑	❑	❑

What did you like about the product?

What did you dislike about the product?

How often would you eat this product?

- ❑ **Very often**
- ❑ **Frequently**
- ❑ **Now and then**
- ❑ **Occasionally**
- ❑ **Hardly ever**
- ❑ **Never**

Would you buy this product?

- ❑ **Yes, definitely**
- ❑ **Yes, probably**
- ❑ **No**
- ❑ **Don't know**

Please try product ?? and then answer the following questions.

Please tell us how you rate the product OVERALL by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

We would now like you to rate the product on several characteristics

[Image 2]

Please tell us how you rate the APPEARANCE by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the SHAPE by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the COLOUR by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Please tell us how you rate the FLAVOUR by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

How do you rate the sweetness?

5 - Far too sweet	*4 - Slightly too sweet*	*3 - Just right*	*2 - Not quite sweet enough*	*1 - Nowhere near sweet enough*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the sourness?

5 - Far too sour	*4 - Slightly too sour*	*3 - Just right*	*2 - Not quite sour enough*	*1 - Nowhere near sour enough*	*No opinion*
❑	❑	❑	❑	❑	❑

Please tell us how you rate the TEXTURE of the product by giving it a mark out of 10, where 10 means it is extremely good and 0 means it is extremely poor.

10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

How do you rate the firmness?

5 - Far too soft	*4 - Slightly too soft*	*3 - Just right*	*2 - Slightly too hard*	*1 - Far too hard*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the juiciness?

5 - Far too juicy	*4 - Slightly too juicy*	*3 - Just right*	*2 - Slightly too dry*	*1 - Far too dry*	*No opinion*
❑	❑	❑	❑	❑	❑

How do you rate the crispness?

5 - Far too crisp	*4 - Slightly too crisp*	*3 - Just right*	*2 - Not quite crisp enough*	*1 - Nowhere near crisp enough*	*No opinion*
❑	❑	❑	❑	❑	❑

What did you like about the product?

_____

_____

_____

_____

_____

_____

_____

What did you dislike about the product?

_____
_____
_____
_____
_____
_____
_____

Which of the following statements do you most agree with?

- ❑ **Very often**
- ❑ **Frequently**
- ❑ **Now and then**
- ❑ **Occasionally**
- ❑ **Hardly ever**
- ❑ **Never**

Would you buy this product?

- ❑ **Yes, definitely**
- ❑ **Yes, probably**
- ❑ **No**
- ❑ **Don't know**

Of the two products you have tried, which did you prefer?

- ❑ **Prefer product ??**
- ❑ **Prefer product ??**
- ❑ **No preference for either**

Appendix 4

Ceeval
(Red Alkmene or Red Windsor)
A higher-coloured clone of Alkmene (Early Windsor)
(Geheimrat Doktor Oldenburg x Cox's Orange Pippin)

Origin:
Ceeval (Red Alkmene) is a higher-coloured clone of Alkmene. Also appears with a spelling of *'Cevaal'* in some European countries.

Type / Use: Second early dessert apple

Picking Date: Early September (same as Worcester Pearmain)

Season: September - October

Appearance: Medium sized fruits. Skin russet often present (Cox's Orange Pippin type).
Rich, striped, orange / red colour over yellow background. Fruits sometimes lop-sided. Attractive.

Quality: Rich, aromatic, honeyed flavour, crisp, juicy flesh, tinged yellow.
Many Cox attributes.

Cropping: Heavy (light in early years). Requires thinning to achieve good fruit size.

Storage: Shorter season than Cox – short term only (few weeks).

Vigour: Good, upright spreading.

Pollination: Pollination group 2.

Resistance: Possible resistance to scab. Reputed mildew resistance, but trials have proved the variety is susceptible.

Other information: Ripens before Cox but shorter season.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure	Average Sugar (% SS)	Average Starch pattern
2000	**12.9.00 PF**	**164.7**	**72.4**	**68.3**	**13.7**	**7C**

2001	**11.9.01 PF**	**137.1**	**65.7**	**69.1**	**12.6**	**8C**
2002	**8.9.02 PF**	**175.6**	**74.0**	**74.2**	**13.5**	**7C**
2003	**3.9.03 PF**	**169.8**	**72.2**	**70.7**	**15.0**	**8C**
2004	**6.9.04 PF**	**168.2**	**70.3**	**72.8**	**14.6**	**8C**

PF = Poultry Farm, Marden, Kent.

Performance in taste evaluations 2000:

Aroma:	2.3
Firmness:	2.3
Juiciness:	2.2
Crispness:	2.2
Sweetness:	2.6
Acidity:	2.0
Shape:	2.3
Colour:	3.0

General comments / observations

In hindsight, the apple was possibly picked slightly late, and some fruits were rather dry, with a poor texture and slightly tacky finish. The colour and flavour were rated as 'good.' This variety would undoubtedly have achieved better scores if picked earlier. Overall rating **'Pleasant'**

2001

Ceeval evaluated well in 2001, achieving an overall rating of **'good.'** Fruit size and maturity were more consistent, although several pick-overs are necessary to achieve a uniform harvest.

2002

Firmness:	2.4
Juiciness:	3
Crispness:	2.4
Sweetness:	2.4
Acidity:	2.2
Shape:	2.4
Colour:	2.2

General comments / observations

Conical shape – visually good
Looks rather over-mature
Poor colour, high russetting
Mix of different sized fruits and maturities
Odd texture – reasonable eat
Short shelf life
Overall rating: **Fair**

2003

Firmness:	3.8
Juiciness:	3.4
Crispness:	3.5
Sweetness:	2.5
Acidity:	2.5
Shape:	3.5
Colour:	3.3

General comments / observations

Rated relatively highly. At best, apples are well flavoured, crisp and juicy. The season is very short and picking date is critical. Several pick-overs may be necessary to avoid mixed fruit maturity.
Overall rating: **Good**

2004

Performance in Sainsbury's Product Evaluation (*vs Discovery*)

Attribute ratings show the score obtained for each quality characteristic out of a total of 10.

% +ve = percentage of consumers who responded favourably to the apple and would buy it again.

% -ve = percentage of consumers who responded negatively to the apple and would not buy it again.

Variety	**Appearance**	**Shape**	**Colour**	**Flavour**	**Texture**	**Overall average**	**% +ve**	**% -ve**
Ceeval	6.76	7.53	7.16	6.73	7.15	6.9	55%	46%
Discovery	7.44	7.45	7.38	6.25	5.58	6.2	38%	61%

Summary of preliminary observations on agronomic performance:
Trees were assessed from the APRC funded variety trial of 42 varieties at Peter Hall's Farm, Marden (no inputs other than herbicide to control weeds), and the newly planted variety trial on VF216 at East Malling Research, (managed under organic protocols) between 2000 – 2004.

Tree Vigour / Habit: Moderately vigorous, upright, slightly spreading habit. Heavy bloom density in 2004, leading to heavy crop.

Pests and Diseases: Appears to be susceptible to mildew. Possibly prone to rosy apple aphid.
High tolerance of scab. Fruit scab apparent in 2004 but not on leaves.

Comments: Attractive, conical fruits – some quite large (>65mm). Requires thinning.

Suppliers:

BOOMKWEKERIJ FLEUREN
Veldstraat 56, 5991 AE BAARLO, THE NETHERLANDS
***tel:** +31 (0)77 – 4772100, - **fax**: +31 (0)77 - 4771312*
E-Mail: info@fleuren.net, www.fleuren.net (Organic trees available to order)

F.P. MATTHEWS LTD
Berrington Court
Tenbury Wells
Worcestershire
WR15 8TH
tel: 01584 810214, **fax:** 01584 811830 (*Non organic trees only*)

Rajka

(Sampion x Katka)

Origin:
Czech Republic. Institute of Experimental Botany at Louda, Prague.
Commercial since 1998.

Type / Use: Dessert apple.

Picking Date: Late September - early October

Season: October - December

Appearance: Medium – large, round fruit. Smooth skin, slightly greasy with slight russeting around the stalk. Yellow background colour with 50-75% faded red foreground colour. Some russeting in stalk cavity which may extend out over shoulders.

Quality: Flesh yellowish with a medium grained texture, firm, juicy, sweet-subacid, medium aromatic, with a hint of strawberry.

Cropping: Good and regular cropping – precocious. Fruits do not fall prematurely. Some fruit thinning is recommended to prevent overcropping and biennial bearing.

Storage: Approximately 4 months in air.
Requires good storage (ULO) to keep flesh firmness.

Vigour: Moderately vigorous – vigorous, spurs freely, good branching. No specific requirements for rootstocks or pruning. Suitable rootstock vigour is from M9 – MM106.

Pollination: Pollination group 2. Suitable pollinators include Topaz and *Malus* (crab apples) such as Golden Horne and Evereste. A good pollinator for other varieties.

Resistance: Resistant to scab and tolerant to mildew. Good resistance to scab shown in trials at Dresden-Pillnitz, Germany.

Other information: May be suited to cooler areas.

Year	Pick date and location	Average Fresh weight	Average Diameter (mm)	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**20.9.00 R**	**147.1**	**71.2**	**79.2**	**12.6**	**8C**
2001	**24.9.01 R**	**254.0**	**84.2**	**75.2**	**14.0**	**7C**

2002	**23.9.02 R**	**159.8**	**71.8**	**69.8**	**11.76**	**8C**
2003	**16.9.03 R**	**186.4**	**78.4**	**83.2**	**12.5**	**8C**
2004	**17.9.04 R**	**169.7**	**72.3**	**74.1**	**13.6**	**7C**

R = Rock's Farm, East Malling

Performance in taste evaluations 2000:

Aroma:	3.5	**General comments / observations**
Firmness:	3.0	Quality was good and although one person thought the flavour was bland, others recorded a 'rich, aromatic eat – lemony and nutty / caramel.' Texture was excellent and appearance was good - possibly skin finish a little tacky and one person found it a little tough.
Juiciness:	3.3	
Crispness:	4.0	
Sweetness:	2.3	
Acidity:	2.3	
Shape:	3.2	
Colour:	3.3	Overall rating: **Pleasant– Good**

2001

Rajka received good scores for taste and appearance and remains a popular choice for the final short-list. Storage potential in air appears limited and cracking around the stalk end (basin) could be a problem from some sites.

2002

Firmness:	3.1	<u>General comments / observations</u>
Juiciness:	2.6	Non descript, greasy
Crispness:	3.1	Very average – poor eat
Sweetness:	2.1	No flavour, bland
Acidity:	2.4	Refreshing
Shape:	3.2	Good appearance
Colour:	3	Overall rating: **Fair**

2003

Not evaluated during 2003, but fruits were sampled during the review meeting. Flavour was very good. Appears to be prone to greasy skin – especially when held in storage, therefore probably not suitable for long-term keeping. Air storage is relatively poor.

2004

Performance in Sainsbury's Product Evaluation (*vs* Resi)

Attribute ratings show the score obtained for each quality characteristic out of a total of 10.

% +ve = percentage of consumers who responded favourably to the apple and would buy it again.

% -ve = percentage of consumers who responded negatively to the apple and would not buy it again.

Variety	**Appearance**	**Shape**	**Colour**	**Flavour**	**Texture**	**Overall average**	**% +ve**	**% -ve**
Rajka	7.18	7.57	7.46	7.08	7.33	7.14	59	41
Resi	7.46	7.55	7.59	6.73	7.18	6.93	55	45

Summary of preliminary observations on agronomic performance:
Trees were assessed from the small-scale variety trial at Rock's farm (conventional regime) and the newly planted variety trial on VF216 at East Malling Research, (managed under organic protocols) between 2000 – 2004.

Tree Vigour / Habit: Moderately vigorous, upright compact- spreading, narrow branch angles.
Moderate bloom density in 2004, leading to a light-moderate crop, although required thinning in June.

Pests and Diseases: Shows complete scab resistance. Low incidence of mildew and rosy apple aphid.

Comments: Mature trees show relatively good form and growth, fruit remains on tree well, but tendency towards greasiness if over-mature. Trees on VF216 had initial poor growth (due to poor quality graftwood?) and showed signs of drought stress in 2003.

Suppliers:

BOOMKWEKERIJ FLEUREN
- *Besucheradresse:* Veldstraat 56, 5991 AE BAARLO, THE NETHERLANDS
- ***tel:*** +31 (0)77 – 4772100, - ***fax:*** +31 (0)77 - 4771312
- *E-Mail:* info@fleuren.net, www.fleuren.net

(Organic trees available to order)

WALCOT ORGANIC NURSERY

Lower Walcot Farm
Walcot Lane
Drakes Broughton
Pershore, WR10 1NE
Email: enquiries@walcotnursery.co.uk
www.walcotnursery.co.uk
tel: 01386 553697

(*Organic trees available – pre-ordering required for large quantities*)

KEEPERS NURSERY
Gallants Court
East Farleigh
Maidstone Kent ME15 0LE
Email: keepers@simahamid.plus.com
www.keepers-nursery.co.uk

tel: 01622 726465

(Pre-ordering likely to be required for large quantities)

Resi

(Clivia (Oldenburg x Cox Orange Pippin) x Scab resistant breeding line (*Vf*)

Origin:
Germany. Dresden – Pillnitz breeding programme. Commercial since 1996.

Type / Use: Mid-late season dessert apple.

Picking Date: End September.

Season: October – January / February

Appearance: Medium sized fruit, flat round, smooth skinned, non russetted. Background colour yellow, bright red blush up to 80% cover.

Quality: Good dessert apple, relatively sweet (good sugar / acid balance) and intense fruity aroma. Crisp flesh, juicy and fine-textured.

Cropping: Early to set fruit, high and regular. Fruit thinning may be necessary with a high set.

Storage: Resi should not be stored under 2°c in the cold store.

Vigour: Rather weak. Open crown with horizontal fruiting branches – good framework. Renewal pruning of fruiting branches may be necessary.
Trials in Hungary on M26 rootstocks have given a spreading, moderately dense canopy.

Pollination: Pollination group 3. A very good pollinator for other varieties.

Resistance: Resistant to scab (*Vf*), fireblight, red spider mite and tolerant of mildew.

Trials in Germany at Dresden-Pillnitz have shown good scab resistance but some susceptibility to mildew.

Other information: Suitable for all production systems.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**Mid Sept ***	**113.5**	**61**	**69**	**14.0**	**10C**
2001	**Mid Sept**	**120.7**	**63**	**65.2**	**12.9**	**10C**

	*****					
2002	**-**	**-**	**-**	**-**	**-**	**-**
2003	**20.9.03 VF**	**111.1**	**60.2**	**90**	**13.1**	**9C**
2004	**16.9.04 VF**	**123.1**	**63.9**	**88.4**	**13.6**	**9C**

** Fruits supplied from Germany, VF = Village Field 216, East Malling*

Performance in taste evaluations 2000:

Aroma: 2.8
Firmness: 3.6
Juiciness: 2.7
Crispness: 3.2
Sweetness: 2.4
Acidity: 2.6
Shape: 3.4
Colour: 3.5

Resi (fruits from Germany) was rated '**good – very good'** overall although one person found it 'bad' and another, 'indifferent.' Most people detected a good sweet tang and estery 'strong banana flavour' although others found it 'alcoholic' (possibly over-mature) with an 'acid after-taste.' Quality was fairly good, in terms of texture, and appearance was also rated highly ('great background colour').

2001

Fruit sourced from Germany. Resi received favourable scores during evaluation in both 2000 and 2001, although limited fruit samples were available from Germany. Shelf life appears promising.

2002

No fruit available

2003

Fruits were taken from VF216.

Firmness: 3.8
Juiciness: 3.2
Crispness: 3.7
Sweetness: 2.9
Acidity: 2.7
Shape: 3.6
Colour: 3.6

General comments / observations

Rated relatively highly. Fruit was well flavoured with a good sugar / acid balance. Slightly Gala-like in appearance with a nice pink-red blush. Fruits were small but improved size could be achieved from mature trees with adequate thinning.

Overall rating: **Good**

2004

Performance in Sainsbury's Product Evaluation (*vs* Rajka)

Attribute ratings show the score obtained for each quality characteristic out of a total of 10.

% +ve = percentage of consumers who responded favourably to the apple and would buy it again.

% -ve = percentage of consumers who responded negatively to the apple and would not buy it again.

Variety	**Appearance**	**Shape**	**Colour**	**Flavour**	**Texture**	**Overall average**	**% +ve**	**% -ve**
Rajka	7.18	7.57	7.46	7.08	7.33	7.14	59	41
Resi	7.46	7.55	7.59	6.73	7.18	6.93	55	45

Agronomic performance of trees on VF216

Fruit Set: Heavy (hand thinned). Heavy bloom density observed in April 2004.

Fruit characteristics: Very long stalks. Fruit can be hard to pick. Attractive, conical Gala-like form and colour.

Tree Vigour / Habit: Vigorous, spreading, very well branched

Pests and Diseases: Some rosy apple aphid present. No scab observed between 2000-2004. Average susceptibility to mildew.

Comments: Trees showed symptoms of drought stress in 2003.

Suppliers:
No suppliers listed in the UK at present.

Propagation / plant variety rights should be obtained from:

Federal Centre for Breeding Research on Cultivated Plants (BAZ)
INSTITUTE OF FRUIT BREEDING (IOZ)
Pillnitzer Platz 3a
D-01326 Dresden
Tel.: *++49(0)351 / 2 61 62-14.* ***Fax:*** *++49(0)351 / 2 61 62-13*
e-mail: *bafz-oz@bafz.de*. www.bafz.de

Rubinola

(Prima x Rubin)

Origin:
Czech Republic. Institute of Experimental Botany at Louda, Prague. Introduced 1980.

Type / Use: Mid-late season dessert apple.

Picking Date: Mid September

Season: September - December

Appearance: Attractive, medium fruit size, spherical fruit shape, slightly flattened. Smooth skin, slightly greasy with light russeting around stalk. Background is yellow-orange flushed 75% faded red foreground. Stalk is medium-long.

Quality: Firm flesh, fine-textured, juicy with a very good sweet-sour, aromatic flavour.

Cropping: Crops regularly – comes into bearing early. Mature trees crop well and regularly and produce fruits of uniform size. Fruit thinning is not usually required. Inclined to tip bearing fruiting habit. Fruits hang well into maturity.

Storage: Stores until end of March in cold store at ULO
CA regime: 2°C, 92% humidity, 3% CO_2, 2% O_2
Air storage: 1°C, 92% humidity.

Vigour: Reputed to have strong, spreading, vigorous growth, with moderate branching. Requires a rootstock weaker than M9 to curb its vigorous growth. Reduction of vigour can also be achieved by high budding (35-40cm) of nursery trees.
To reduce vigour, it is recommended that winter pruning should be very limited (just reduce density by removing a limited number of shoots or branches). Bending or summer pruning is preferable to promote the formation of fruiting spurs (important for young trees). Fruiting branches can be tied down into horizontal positions and only carefully rejuvenated.
Suitable for intensive production.

Pollination: Pollination group 3. Suitable pollinators include scab resistant *Malus* (crab apples) such as Golden Hornet and Evereste or other apple varieties such as *Rajka* and *Lena*. A good pollinator for other varieties.

Resistance: Reputed resistance to scab and high tolerance of powdery mildew.
Good scab and mildew resistance shown in trials at Dresden-Pillnitz, Germany.

Other information:

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure	Average Sugar (% SS)	Average Starch pattern
2000	**13.9.00 R**	**206.4**	**79.4**	**90.2**	**13.6**	**8C**
2001	**24.9.01 R**	**216.8**	**82.5**	**79.1**	**13.2**	**10C**
2002	**17.9.02 R**	**150.2**	**71.0**	**80.8**	**11.5**	**9C**
2003	**16.9.03 R**	**189.4**	**73.2**	**87.7**	**12.4**	**9C**
2004	**20.9.04 R**	**201.7**	**77.4**	**86.0**	**13.0**	**9C**

R = Rock's Farm, East Malling

Performance in taste evaluations 2000:

Aroma:	3.0
Firmness:	3.3
Juiciness:	2.7
Crispness:	2.7
Sweetness:	3.3
Acidity:	2.7
Shape:	3.0
Colour:	3.0

Quality was above average with a good sugar / acid balance and strong cream flesh. Flavour was very good – 'rich, deep – pineapple and bananas – honeyed) with a sweet tang.' The fruit had rather a yellow background and greasy finish (also net-like russet) and the fruit may have been slightly over-mature, but were nonetheless good. Overall rating: **Good**

2001

Rubinola evaluated very successfully in 2001, achieving a high standard of fruit quality and excellent storage potential. There were concerns about the slight characteristic cracking around the basin (stalk end) but it was agreed this would have little bearing on storage quality. Fruit greasiness may be a potential problem but is not a major concern at present.

2002

Firmness:	3
Juiciness:	3.4
Crispness:	3.8
Sweetness:	2.5
Acidity:	2.7
Shape:	2.7
Colour:	2.9

<u>General comments / observations</u>
A very good eat – sweet, crisp and juicy
A little lacking in flavour
Cracks around stalk end
Synthetic texture, tough skin
Poor skin finish – greasy and lenticel spot
Flesh is crisp but not dense
Good colour, texture and shape
Overall rating: **Pleasant**

2003

Firmness:	3.7
Juiciness:	3.2
Crispness:	3.6
Sweetness:	3.7

<u>General comments / observations</u>
Fruits were sweet, crisp and juicy, Rubinola continued to perform consistently well this year.
Lenticel spot and cracking around the stalk end

Acidity: 2.4 continue to be characteristics of the variety.
Shape: 3.7 Overall rating: **Good – Very good**
Colour: 3.8

2004

Performance in Sainsbury's Product Evaluation (*vs* Red Falstaff)

Attribute ratings show the score obtained for each quality characteristic out of a total of 10.

% +ve = percentage of consumers who responded favourably to the apple and would buy it again.

% -ve = percentage of consumers who responded negatively to the apple and would not buy it again.

Variety	Appearance	Shape	Colour	Flavour	Texture	Overall average	% +ve	% -ve
Rubinola	7.18	7.51	7.74	7.64	7.58	7.54	73%	27%
Red Fstff	7.24	7.63	7.48	6.12	6.72	6.50	45%	56%

Summary of preliminary observations on agronomic performance:

Trees were assessed from mature planting on M9 rootstock at Rock's farm and the newly planted variety trial on VF216 at East Malling Research, (managed under organic protocols) between 2001 – 2004.

Tree Vigour / Habit: Upright, strong framework on mature trees. Moderately vigorous, spreading, bare scaffolds. Wide branch angles. Sparse foliage development but reliable cropping. Fruits hang on very long stalks.Trees on VF216 show weak vigour and little growth (poor quality graftwood or canker?). Very light bloom density and crop load in 2004.

Pests and Diseases: No scab observed during 2000-2004. Relatively low incidence of mildew. Some rosy apple aphid . Prone to canker. Appears prone to *Phoma* leaf spot.

Suppliers:

BOOMKWEKERIJ FLEUREN
- *Besucheradresse:* Veldstraat 56, 5991 AE BAARLO, THE NETHERLANDS
- ***tel:*** +31 (0)77 – 4772100, - ***fax:*** +31 (0)77 - 4771312
- *E-Mail:* info@fleuren.net, www.fleuren.net

(Organic trees available to order)

KEEPERS NURSERY
Gallants Court
East Farleigh
Maidstone Kent ME15 0LE
Email: keepers@simahamid.plus.com
www.keepers-nursery.co.uk
tel: 01622 726465

(Pre-ordering likely to be required for large quantities)

Bud wood with Virus-Free certification is available from:

VERMEERDERINGSTUINEN NEDERLAND
Tienrayseweg 9a
NL – 5961 NK Horst
e-mail: info@vermeerderingstuinen.nl
Contact person: Dr R.P.J.M. Koning
Propagation of the variety should be carried out under agreement with the breeder, Jaroslav Tupy. (Email: Tupy@ueb.cas.cz).

Rubinstep

(Clivia x Rubin)

Origin:
Czech Republic. Result of collaboration between the Breeding and Research Institute of Pomology in Holovousy, the Catholic University of Louvain and the N.V. Johan Nicolai.

Type / Use: Mid-season dessert apple.

Picking Date: Mid – late September.

Season: September - ? Very long shelf

Appearance: Attractive. Orange-red fruit. Flattened shape, good size.

Quality: Very firm fruit flesh with a very good flavour. High sugar levels. Firmness 75N.

Cropping: A medium cropper – fruit thinning is not usually necessary. Yields are very similar to Golden Delicious and Jonagold (Holovousy trials data 2001-2004). Can be slow to come into bearing, with limited branching and long shoots, although proper training after planting should alleviate this (see notes below). Tip bearing fruiting habit.

Storage: Stores until June in ULO. Some resistance to storage disorders.

Vigour: Strong vigour.

Recommendation from the breeder (Jan Blazek):

Pruning young trees:
It is essential to train young trees well after planting to achieve good early yields. Without pruning, trees have a tendency to produce shoots with 'bare wood,' (but pruning can remove most of the fruit buds since the variety is tip-bearing). It is therefore best to start with a well-feathered nursery tree or use a 'knip baum' tree with side branches. When planting a whip, cut it back and encourage side-branching by 'pegging',' removing the top of lateral buds, or by bending. Long shoots should be pinched or shortened by pruning at the beginning of August. Successful development of numerous side branches and laterals during the first two years after planting will ensure that the trees become precocious and productive.

Top working and nursery trees:
These may require summer heading of shoots after grafting by one-third to one-half to develop a good branch framework and prevent the trees growing too vigorously.

Pollination: Pollination group 3.

Resistance: Scab resistance (polygenic). Appears prone to rosy apple aphid.

Other information: Late flowering. Currently applying for variety protection in the E.C in the name of the Institute of Holovousy.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**End Sept***	**218.9**	**80.4**	**92.1**	**14.3**	**8C**
2001	**End Sept***	**215.0**	**78.6**		**14.9**	**8C**
2002	**-**	**-**	**-**	**-**	**-**	**-**
2003	**End Sept***	**189.7**	**77.2**	**94.4**	**13.7**	**8C**
2004	**28.9.04 * 9.9.04 VF**	**- 185.3**	**- 66.9**	**- 88.4**	**- 13.0**	**- 8C**

** Fruit sourced from the Czech Republic. VF = Village Field 216, East Malling.*

Performance in taste evaluations 2000- 2001:
The variety was well received by the panel in both 2000 and 2001. Fruit samples sourced from Czech Republic.Fruits are well sized with a good shape, although samples sent from overseas appear slightly over-mature. Rubinstep has a good reputation for fruit quality and disease resistance.

2002
No fruit available

2003

Firmness:	3.7	General comments / observations
Juiciness:	2.5	Fruit sourced from Czech Republic. Mixed ratings –
Crispness:	3	many subtle flavours and taints were detected, but
Sweetness:	2.8	nothing special. Fruit size and appearance were good.
Acidity:	2.3	Improved eating quality may be obtained using UK
Shape:	3.6	fruits.
Colour:	3.3	Overall rating: **Good**

2004
Performance in Sainsbury's Product Evaluation (*single test)*
Attribute ratings show the score obtained for each quality characteristic out of a total of 10.

% +ve = percentage of consumers who responded favourably to the apple and would buy it again.
% -ve = percentage of consumers who responded negatively to the apple and would not buy it again.

Variety	Appearance	Shape	Colour	Flavour	Texture	Overall average	% +ve	% -ve
Rubinstep	7.7	7.4	7.7	7.7	7.6	7.5	76%	24%

Agronomic performance of trees on VF216:
Tree Vigour / Habit: Upright, strong framework. Good vigour.
Pests and Diseases: Appears very prone to rosy apple aphid. Leaf scab present in 2004 only. Relatively low incidence of mildew.

Suppliers:

N.V. Johan Nicolaï
(Fruit Tree Nursery)
Gorsem Dorp 51
B-3803 Sint-Truiden
Tel.: +32 (0)11 68 37 79
Fax: +32 (0)11 70 20 01
Email: info@nicolai.be, www.nicolai.be

(Trees only available on M27 rootstock at present)

Edward V11

(Blenheim Orange x Golden Noble)

Origin:
UK, first recorded 1902. Introduced in 1908 by Messrs Rowe of Worcester.

Type / Use: Late Season Culinary apple

Picking Date: Mid October

Season: December - April

Appearance: Medium sized fruits, round – flat round. Can be slightly lop-sided. Bright green – becoming pale yellow. Some fruits have purplish brown flush. No stripes. Numerous lenticels. Skin smooth and dry.

Quality: Pale yellow flesh, firm, rather coarse-textured. Fairly juicy and acid. Excellent cooker, breaks up completely to a red translucent creamy puree. Not as acidic as Bramley. Becomes sweeter in storage, cooking more firmly and makes pleasant, brisk eating apple. Skin a little tough.

Cropping: Rather slow to come into bearing. Moderate cropping. Can be difficult to crop in some situations.

Storage: Reputedly late-keeping. Scald can be a problem in storage at certain temperatures.

Vigour: Moderately vigorous. Neat, compact, upright habit. Hardy.

Pollination: Late flowering – escapes spring frosts but may suffer lack of pollinators.

Pollination group 6.

Resistance: Scab resistant. Prone to bitter pit.

Other information: Popular garden variety – grown for sale to small extent.
Planted on a limited scale commercially.

Year	Pick date and	Average Fresh	Average Diameter	Average Pressure	Average Sugar	Average Starch

	location	weight		(N)	(% SS)	pattern
2000	**2.10.00 PF**	**298.4**	**91.7**	**85.2**	**11.0**	**2C**
2001	**28.9.01 PF**	**305.4**	**88.6**	**88.5**	**11.3**	**1C**
2002	**30.9.02 PF**	**255.1**	**72.6**	**79.4**	**10.8**	**1C**
2003	**4.10.03 PF**	**301.1**	**90.6**	**90.2**	**11.4**	**2C**
2004	**2.10.04 PF**	**312.4**	**93.3**	**87.6**	**11.9**	**2C**

PF = Poultry Farm, Marden

Agronomic performance of trees on VF216 and from Poultry Farm, Marden.

Fruit Set: Medium- heavy at Poultry Farm. Heavy on VF216 in 2004.
Tree Vigour / Habit: Moderately vigorous, upright, cup-shaped, sturdy. Some bare scaffold branches.
Pests and Diseases: Mildew on untreated leaves. Suffered severe rosy apple aphid infestation at Poultry Farm in 2002. Also noted on VF216. No scab.
Comments: Bitter pit common on fruits at Poultry Farm.

Suppliers:

Widely available from most fruit tree nurseries, although pre-ordering likely to be required for large quantities.

Encore

(Warner's King x Northern Greening)

Origin:
Raised by Charles Ross at Welford Park, Newbury, Berks. First recorded 1906.

Type / Use: Late – very late season culinary apple.

Picking Date: Early October

Season: December - April

Appearance: Ground colour bright green, becoming greenish-yellow – blotched with patches of green undertone. Brownish red-flush – some fruits all green. Broad broken red stripes, little or no russet. Some scarf skin at base. Skin very smooth and greasy. Round to oblong-shape, rather irregular, sometimes flat or lop-sided. Flattened at base and apex. Large to very large sized fruits.

Quality: Creamy white, somewhat soft flesh, rather coarse textured, juicy and subacid. Excellent cooker – quite rich flavour, hardly needs sugar. Remains intact when cooked.

Cropping: Good / Moderate.

Storage: Relatively short-term. Only 2 months in air at 0-0.5°C and also in CA at 2°C (to maintain firmness > 70N).

Vigour: Moderately vigorous, upright spreading, spurs very freely.

Pollination: Pollination group 3.

Resistance: Scab resistant.

Other information: One of the best cooking apples. Primarily exhibition and garden variety but grown commercially on small scale in UK. Good variety for frosty areas.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**2.10.00 B**	**176.2**	**65.2**	**77.6**	**13.8**	**6C**

2001	**10.10.01 B**	**180.4**	**70.6**	**71.0**	**12.0**	**6C**
2002	**8.10.02 B**	**189.1**	**71.4**	**71.4**	**12.9**	**6C**
2003	**15.10.03 B**	**179.5**	**68.2**	**73.7**	**13.5**	**7C**
2004	**-**	**-**	**-**	**-**	**-**	**-**

B = Brogdale (National Fruit Collections)

Agronomic performance of trees on VF216

Fruit Set: Very light

Tree Vigour / Habit: Moderately vigorous, upright habit, compact with narrow branch angles. Some good, long extension growth in 2002-03. Moderate crop load in 2004 from very light bloom.

Pests and Diseases: Green apple aphid and mildew present in most years. Leaf and fruit scab evident in 2004 only.

Suppliers:

Available from specialist fruit tree nurseries, although pre-ordering likely to be required for large quantities.

Howgate Wonder

(Blenheim Orange x Newton Wonder)

Origin:
Raised on Isle of White, UK in 1915-16 by Mr G. Watton of Howgate Lane, Bembridge, Isle of Wight. Introduced 1932 by Stuart Low & Co of Enfield.

Type / Use: Late Season Culinary apple

Picking Date: Early October

Season: November - March

Appearance: One of largest cooking apples in cultivation today. Ground colour pale green – becoming pale / clear yellow. Brownish red flush – changes to orange-red. Broad, broken stripes of dark red or scarlet. Skin very smooth, dry, shiny and russet free. Traces of scarf skin. Short round-conical shape. Fairly regular and angular – sometimes lop-sided, very broad and flattened at base.

Quality: Creamy white flesh, firm fine-textured, juicy, quite sweet when ripe with faint aromatic flavour – cooks well, breaks up almost completely.

Cropping: Heavy and regular when fully established.

Storage: Stores well but becomes very greasy. Reasonably good storage for 3 months at 0-0.5°C in air.

Vigour: Moderately vigorous, upright spreading, spurs freely.

Pollination: Pollination group 3.

Resistance: Resistant to mildew. Appears to be very resistant to frost and can produce fruits even after a frosty spring.

Other information: Grown commercially to some extent in UK – also useful exhibition and garden variety.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**2.10.00 B**	**192.4**	**72.8**	**80.1**	**13.7**	**6C**

2001	**19.9.01 B**	**265.8**	**87.4**	**77.9**	**12.6**	**2C**
2002	**1.10.02 B**	**261.4**	**85.1**	**76.3**	**13.0**	**4C**
2003	**11.10.03 B**	**298.7**	**90.4**	**75.8**	**14.1**	**7C**
2004	**8.10.04 BW**	**215.3**	**77.1**	**77.9**	**13.8**	**4C**

B = Brogdale (National Fruit Collections), BW = Broadwater Farm, West Malling.

Agronomic performance of trees on VF216

Fruit Set: Light in early years. Heavy in 2004.
Tree Vigour / Habit: Moderately vigorous, upright, compact and sturdy habit. Long extension growth and large leaves. Very large fruits.
Pests and Diseases: Appears prone to rosy apple aphid and only tolerant of mildew
Comments: Trees showed drought stress in 2003, although were grafted later than other varieties so had not had so long to establish.

Suppliers:

Widely available from most fruit tree nurseries, although pre-ordering likely to be required for large quantities.

Pikant

(Undine x Carola)

Origin:
Germany. Institute for fruit research, Pillnitz. Introduced 1988.

Type / Use: Dessert apple for the fresh market or processing.

Picking Date: Mid September

Season: September – December / January. Excellent for Christmas sales.

Appearance: Large sized fruits, round shape – slightly flattened with faintly showing stripes. Background colour is yellow – solid red flush (50-90%).

Quality: Sweet – sour taste with strong harmonious flavour. Reminiscent of Carola.

Cropping: Good. High rate of fruit set – requires thinning. High yield. Spur bearer.

Storage: Standard storage until Christmas, cold (air) and CA storage until January / February with firmness >60N. (No shrivelling – few storage losses).

Vigour: Moderately vigorous – well branched – requires regular pruning. Dwarfing or medium – dwarfing rootstock required.

Pollination: Pollination group 3.

Resistance: Slightly susceptible to mildew and scab.

Other information: A productive new cultivar with large fruit and a long period of ripeness from harvest – January, excellent for Christmas sale.

Year	Pick date and location	Average Fresh weight	Average Diameter	Average Pressure (N)	Average Sugar (% SS)	Average Starch pattern
2000	**7.9.00 R**	**235.4**	**80.1**	**68.7**	**10.2**	**6C**
2001	**13.9.01 R**	**187.0**	**76.0**	**68.1**	**11.5**	**7C**
2002	**10.9.02 R**	**186.6**	**77.8**	**77.9**	**12.1**	**7C**
2003	**9.9.03 R**	**200.3**	**79.4**	**71.0**	**11.6**	**6C**
2004	**11.9.04 R**	**219.4**	**83.5**	**74.2**	**11.6**	**6C**

R = Rock's Farm, East Malling

Agronomic performance of trees on VF216

Fruit Set: Medium
Tree Vigour / Habit: Upright, weakly spreading. Small leaves.
Pests and Diseases: Mildew on untreated leaves, slight rosy apple aphid. No scab found.
Comments: Fruits tend to ripen erratically. Several pick-overs required. Varying sized fruits – some very large.

Suppliers:
No suppliers listed in the UK at present.

Propagation / plant variety rights should be obtained from:

Federal Centre for Breeding Research on Cultivated Plants (BAZ)
INSTITUTE OF FRUIT BREEDING (IOZ)
Pillnitzer Platz 3a
D-01326 Dresden
Tel.: *++49(0)351 / 2 61 62-14.* ***Fax:*** *++49(0)351 / 2 61 62-13*
e-mail: *bafz-oz@bafz.de*. www.bafz.de

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