

Project Report

Varieties and Integrated Pest and Disease Management Programme for Organic Apple Production in the UK.

Background:

Since the 1990s, there has been strong and increasing demand for organic produce, including fruit, with apples being the most popular commodity in the organic fruit sector. Overall consumption of apples in the UK has remained static, yet more and more consumers are switching to organically produced fruit. This demand is expected to continue to rise, yet over 90% of current supplies are imported. The volume of UK production has remained very small and cannot keep pace with rising demand. Fruit is very difficult to grow organically and organic apple production in particular is beset by many pest and disease problems. At the project outset, existing methods of organic apple production in the UK were identified as unsatisfactory, resulting in low and erratic yields of poor quality fruit. Lack of suitable varieties (together with lack of pest and disease resistance or tolerance) was also hindering production. The diseases apple scab and powdery mildew and pest rosy apple aphid have the potential to be particularly debilitating in organic systems. There are only a handful of existing organic top fruit growers in the UK supplying UK supermarkets (where over 80% of all organic fruit is sold). This lack of UK production reflects the difficulty of growing apples organically in the UK. After wide consultation with the industry, it was noted that unless new developments in research were undertaken to facilitate the production of organic apples in the UK, demand would continue to be met largely through imports and sales of UK-produced organic fruit would be restricted to a very narrow seasonal window.

Objectives:

The aims of this five-year project were:

- 1) To develop and refine an innovative Integrated Pest and Disease Management (IPDM) programme for organic apple production in the UK.
- 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, juicing and processing) and are suitable for UK production.
- 3) Test a range of alternative organically approved plant protection products against apple scab and powdery mildew.
- 4) To determine and optimise the efficacy of six organically acceptable foliar spray treatments for control of rosy apple aphid.

The project began in March 2000 and was funded by DEFRA under the HortLINK scheme. Members of the project consortium included growers, suppliers and researchers. The project was co-ordinated by Adrian Barlow, chief executive of English Apples and Pears and chairman of the Bramley Campaign, and the scientific research was led by East Malling Research (formerly HRI), based near Maidstone, in Kent.

Consortium members:

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

Methodology:

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

Two large-plot field experiments were set up to evaluate improved methods of IPDM. The first was sited in an established organic Fiesta (Red Pippin) orchard at Oakwood farm, Robertsbridge, East Sussex (by kind permission of E H Wilson & Sons). The orchard was 1.4 ha in size, initially planted as a conventional orchard in 1994 on MM106 rootstock (row spacing 4.95m and tree spacing 3.3m). The orchard began conversion to organic production in 1997 and had reached organic status 3 years later. Fiesta is a conventional apple variety which is known to be highly susceptible to scab and moderately susceptible to mildew. The treatments evaluated at this orchard were: a set experimental programme, the grower's own organic pest and disease control programme, and an untreated control.

The second site represented a slightly different scenario in that it was a newly purpose-planted organic orchard with two relatively new dessert apple varieties: Topaz (a variety with reputed disease resistance) and Pinova (a variety of low disease susceptibility). This new orchard was approx 1.6ha in size and situated at North Court Fruit Farm, Old Wives Lees, Canterbury, Kent (by kind permission of Robert Balicki). The orchard was initially planted with a range of eight disease resistant varieties in Spring 2000, but these made very poor growth and the decision was later made to grub and re-plant the orchard with well-grown, feathered, organically certified trees on M9 rootstock during winter 2001-02. This new planting comprised alternating pairs of rows of the two varieties (row spacing 4.0m, tree spacing 2.2m). The treatments evaluated in this orchard were an experimental IPDM programme and an untreated control.

Components of the IPDM programmes

Disease control:

A programme of copper (Cuprolyt) and Sulphur sprays were used on both sites from bud-burst onwards according to weather conditions and levels of disease inoculum for control of scab and mildew. Leaf litter on the orchard floor was destroyed by maceration after leaf fall and before bud burst to try to minimise the amounts of over wintering scab inoculum. Where possible, wood scab was removed during winter pruning. Removal of mildewed shoots (primary mildew) was carried out during flowering and at petal fall.

Pest control:

Control of apple blossom weevil in the established orchard was attempted through the use of Pyrethrum (Py Insect Killer) in the latter 3 years of the project. Earlier attempts by the grower to control the pest using Derris were unsuccessful. Pyrethrum was also applied against rosy apple aphid which became a problem in the new orchard in the last 2 years of the project. Sprays of *Bacillus thuringiensis* (*Bt*) were applied to both orchards to control tortrix and winter moth caterpillars. Where codling moth was a problem, sprays of Granulovirus (Carpovirusine) were applied. Artificial bottle refuges were provided for earwigs and other predators in every tree in the established Fiesta orchard and a wildflower strip was established at the newly planted orchard to encourage beneficial insects.

Assessments:

Assessments of pest and disease levels from each plot were taken at both sites every year during pink bud, early summer and again at harvest. Disease levels on leaves and shoots were scored on each occasion, as were the presence of pests and both leaves and fruits were assessed again in detail at harvest. Pheromone traps were used to record levels of moth pests in each orchard. Nutritional status of the trees and fruits was recorded by taking a sample of leaves and fruits for analysis in late summer and at harvest. The yield and quality of fruit from each plot at harvest were also assessed, from which an economic analysis was made possible. Where appropriate, results were subjected to statistical analysis.

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, juicing and processing) and are suitable for UK production.

Most conventional varieties of apple grown in the UK are very difficult to grow organically due to their high sensitivity to pest and disease problems. Objective 2 of the link project was to identify varieties more suitable to organic production. At the outset of the project, the consortium agreed on a number of selection criteria which included varietal resistance or tolerance to scab and mildew, attractive fruit appearance, good fruit size (>60mm diameter) and good eating quality (e.g. firm, juicy, well textured, good sugar/acid balance and good flavour). A database containing information on more than 150 apple

varieties with suitability for organic production was compiled during the first year of the project. An evaluation panel (comprising marketing and retailing members of the consortium) conducted taste and appearance evaluations on more than 100 dessert varieties and 35 culinary varieties of apple. Repeat evaluations were carried out on almost half of the varieties the following year and culinary varieties were assessed for processing quality at Fourayes Farms to review flavour and consistency after cooking. Fruit samples were sourced from the National Fruit Collections at Brogdale (Faversham, Kent) and, where appropriate, from unsprayed variety trial plots at Poultry Farm, Marden (courtesy of Peter Hall) and from plots at East Malling. Several new varieties were sourced from abroad. After two years, a final selection of 27 varieties was short-listed and an organic variety trial orchard (replicated block design) of these varieties was established at East Malling Research.

Over the next three years, the variety trial was evaluated for pest and disease sensitivity, tree form and habit, shoot growth, floral precocity and yield. Half of the trial orchard received applications of Sulphur sprays to combat disease and half remained unsprayed. The orchard received several applications of compost to the crop rows to boost fertility in most years and a single spray of *Bt* to control moth pests where necessary. Weed control was achieved by shallow rotavation in the crop rows. The trees had been grafted onto 2-year-old ex-Saturn trees on M9 rootstock and established very quickly, with a first light crop 2 years after planting.

Fruit quality evaluations were continually held each year in order to fine-tune the selection and test the consistency of quality of each fruit variety. Preliminary storage trials were also carried out, first in basic air storage regimes and, in the latter year of the project, in a basic CA (Controlled Atmosphere) regime. The results of all these assessments were collated together and the information was used to help decide which varieties to evaluate further.

In the final year of the project, large-scale consumer taste tests were held at the Sainsbury's Centre in Holborn, London, to evaluate a final selection of eleven dessert apple varieties which had been selected as 'most promising' over the previous four years of assessment. These consisted of the varieties Rubinola, Rubinstep, Pinova, Rajka, Delorina, Resi, Ceeval, Discovery, Red Falstaff, Liberty and Ariwa. Approximately 100 fruits of each variety were evaluated over a range of quality criteria using two-way comparison testing for appearance, shape, colour, flavour, texture and overall acceptability. A statistical analysis was carried out to confirm validity of the results.

Objective 3: Test a range of alternative organically approved plant protection products against apple scab and powdery mildew.

In conventional production, the diseases scab and mildew are managed satisfactorily by fungicides. However, 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 control scab and mildew. There is a considerable range of plant protection products based on clay, mineral, compost and algal extracts worldwide that are claimed to have fungicidal properties against diseases on several crops, including apple. The aim of this objective was to acquire and investigate the effectiveness of various alternative products in controlling apple scab and powdery mildew in UK conditions.

This objective was conducted in three phases. A wide range of products were included in the first phase, but less effective ones were discarded in subsequent experiments to enable a more detailed study of the most promising ones. The products tested were Mycosin, Ulmasud B, Herb Silica, Ca(OH)₂, Headland Sulphur, Neudo vital, Lime sulphur, Equisetum, Wetcol 3, Milk, Milsana, Serenade, Liquid silica, Compost tea (fungal), Maxicrop, Polyversum and Farmphos.

Preliminary experiments were conducted in glasshouse compartments or polytunnels to investigate the efficacy of selected organic-compatible chemicals in controlling scab and mildew when applied as a protectant, curative and antisporulant fungicide using MM106 rootstock plants. These plants were inoculated with scab and mildew to ensure presence of the diseases. In the second phase, experiments were conducted on small potted trees in a sand-bed to determine the activity and relative persistence of those products selected from the first phase experiments. Here, no artificial inoculation was used and hence disease development relied on natural inoculum infections. Finally, the most promising products were selected and taken further to be evaluated in orchard trials. Disease assessments were carried out

at regular intervals throughout each phase to assess levels of scab and mildew and a statistical analysis was carried out on all data.

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

Rosy apple aphid (*Dysaphis plantaginea*) is a major insect pest of apple orchards in the UK and has the potential to be particularly troublesome in organic production, where there are currently no approved plant protection products which can effectively control the pest. Potassium soap may give some control, but is not effective enough in severe infestations. Systemic aphicides applied just before flowering in spring are used to control the pest in conventional orchards. The aphids are particularly damaging as they multiply rapidly during the growing season and can remain protected in tightly curled and rolled leaves, a deformity caused by the aphid's feeding habits. Severe infestations can severely weaken trees and are particularly crippling to young orchards in the early phase of establishment. Infested fruits remain small and puckered and are unmarketable. During the summer, winged forms of the aphid migrate to a summer host plant (Plantain). A later winged generation of males and females fly back to apple in the autumn to mate. The females then lay overwintering eggs which will hatch out and continue the cycle in early spring. One possible approach to controlling the pest organically is to target the winged male and female generation as they return to apple in autumn. These aphids are more vulnerable to sprays since they are not protected within tightly rolled foliage. However, timing of spray application is critical. The aim of this objective was to evaluate a range of organically acceptable foliar spray treatments for the control of rosy apple aphid through both spring and autumn applications.

A total of 10 replicated experiments were carried out between 2000 and 2005. In the first year of the project, spray applications were made in the spring to aphid-infested potted trees in a glasshouse, using a motorised air-assisted knapsack sprayer. The products tested were; *Quassia amara*, Azadirachtin, Garlic and Calceolaria, Potassium soap, Rotenone, *Beauveria bassiana* and a conventional aphicide and untreated control. In the other 8 experiments, sprays were applied to large-scale replicated plots in commercial apple orchards at various times in the autumn against the migratory males and female aphids, using the grower's axial fan air blast sprayer. The orchards were mainly of the variety Bramley but a mixed orchard of Discovery and Egremont Russet was also used. These apple varieties are known to be highly susceptible to rosy apple aphid. The autumn experiments explored different times of application of different products and mixes. The aim was to determine the most effective time to spray during the autumn migration period and the most effective product to use. Products tested were Azadirachtin, *Beauveria bassiana*, Calceolaria extracts, Garlic extract, Kaolin, Natural plant extracts, Potassium soap, *Quassia amara* extract, Rotenone, conventional controls of Cypermethrin and Pirimicarb and untreated controls. In most cases, sprays were applied at full rate (1000l/ha).

For the initial spring experiments on potted trees in the glasshouse, assessments of aphid populations were made at one and two week intervals after spraying. The number of aphid colonies on each tree were recorded. For the autumn experiments in the field, assessments of aphid colonies that developed were carried out the following spring at green cluster - pink bud, and repeated again at full bloom. Again, the number of aphid colonies on each of 20 trees per plot were recorded. Records were also made of other aphid species present (e.g. rosy leaf curling aphid, green apple aphid, apple grass aphid).

Results:

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

Scab and mildew

On both orchard sites, the IPDM programme was most successful in increasing yield and quality of organic apples, compared to the grower's own spray programme and untreated controls. Although controversial, three early season sprays of copper (1 pre-bud burst and two at bud burst and mouse ear) gave fairly good early season control of scab on fruit and leaves. However, the spray programmes of copper and sulphur did not prevent damaging scab infection on susceptible varieties in high risk scab years (e.g. 2002) and sulphur had at best only limited activity against scab and high volume sprays at full dose are necessary to control mildew on susceptible varieties. In the newly planted orchard, the scab-resistant variety Topaz gave good yields of high quality fruit but the variety Pinova was found to

be too susceptible to both scab and mildew. Destruction of over wintering sources of scab on leaf litter is important in reducing disease inoculum and removing primary mildew during winter pruning and in spring will also improve control of mildew in the growing season. Alternative products for the control of scab and mildew were trialled in objective 3, but none proved effective.

To avoid spraying, the best approach is to plant new orchards of disease resistant varieties. Scab resistance is vital and mildew resistance is also vital in mildew-prone areas. Converting established conventional orchards of disease-susceptible varieties such as Cox, Gala, Bramley, Fiesta etc to organic production is not likely to be successful. This work highlighted the importance of correct variety selection and the work done in objective 2.

Pests

Apple blossom weevil was the most important pest causing large losses in yield and quality in the established orchard. It did not occur in the newly planted orchard which was isolated from sources of infestation during the first three years of establishment. Two early season sprays of Pyrethrum (Py Insect Killer) were shown to give good (but not complete) control of weevil adults. Spray of Derris were ineffective. However, use of sprays do not fit well with the aims of organic production and alternative control strategies (based on the use of an aggregation pheromone) still need to be developed. Rosy apple aphid caused significant damage to young trees in the newly planted orchard, but was less of a problem in the mature orchard. The variety Topaz was considerably more susceptible than Pinova. Good control was achieved by cutting out affected shoots in spring and early season sprays of Pyrethrum gave some reduction in infestations. Tortrix, Winter, and Codling moth damage was limited in most years at both sites. Sprays of Carpovirusine were very effective against Codling moth but *Bt* were less effective against other moth pests. Pheromone trapping is only permitted for monitoring purposes.

Yield, quality and tree nutrition

The experimental IPDM treatments in both orchards gave a higher yield and better quality fruit (higher percentage of class 1 fruit) than the grower's own control programme and untreated controls in all years, resulting in higher financial returns. The costs of the sprays used on the experimental treatments (at 4% of total costs), were relatively small and easily justified in terms of the increased financial returns. However, Nitrogen levels in the organic orchards were found to be significantly lower than those usually below the target levels considered optimal for conventional production. Applications of organic high-N fertilizer improved levels a little, but there was still cause for concern since low N levels can have significant adverse effects on tree growth and yield. Therefore, for successful organic apple production, provision of N and means of overcoming weed competition for moisture and nutrients are likely to be of vital importance, particularly during orchard establishment.

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, juicing and processing) and are suitable for UK production.

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 consumer acceptance. In addition, each also has a reputed resistance or tolerance to scab, although mildew is likely to remain a problem on all varieties. The varieties Rubinola and Rubinstep also have excellent storage potential. **Full details on each variety can be found at the end of this report.**

Recommended culinary varieties

The varieties Edward VII, Encore, Howgate Wonder and Pikant were identified as the most promising culinary varieties for organic production. 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. (Bramley is very susceptible to scab and can be difficult to grow organically in some situations, despite its vigour). The varieties Edward VII, Encore and Pikant also have reputed resistance or tolerance to scab, although mildew can still be a problem. In contrast, Howgate Wonder has reputed resistance against mildew, but may suffer from scab. **Again, full details for each variety can be found at the end of this report.**

Juicing varieties

The French variety Judeline, a highly disease resistant and productive variety which produces fruits of high juice content with a good sugar – acid balance, was initially selected as having great 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 which are less susceptible to the diseases scab and mildew will continue to fill the organic juice market.

Pest and disease resistance

The organic variety trial which was planted with 28 promising varieties selected by Sainsbury's and Waitrose during the first two years of the project proved that it is very difficult to select varieties with complete resistance to both scab and mildew and that 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 and was apparent in the orchard right from planting. Very few varieties are mildew 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.

Rosy apple aphid was the most troublesome pest in the variety trial orchard. Some varieties were notably more prone than others. Resistance or tolerance to common pests such as aphids 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.

Establishing a new orchard

When planting a new organic 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.

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 or 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.

Objective 3: Test a range of alternative organically approved plant protection products against apple scab and powdery mildew.

Unfortunately, almost all the alternative products tested during the five-year period were not very effective in controlling apple mildew and scab. Of all those tested, only sulphur and frequent

application of low rate copper were effective against powdery mildew and scab, respectively. Sulphur was also relatively effective against apple scab.

Compost teas have been found to control diseases in various crops, although the efficacy of control depends critically on many factors including aeration, pH, compost type and microbial population. However, understanding of the way in which compost teas work remain very limited. Further research is needed in this area before the effects of compost teas against diseases such as scab and mildew can be fully identified.

Of the other products tested, Milsana had a partial effect against powdery mildew, but on its own is unlikely to manage the disease effectively in the UK. Many research studies have indicated that various bicarbonate salts can be used to suppress disease development. Although bicarbonate salts were not tested on apple as part of the LINK project, work done elsewhere in trials at East Malling Research has yielded only disappointing results, as was also the case with work done on phosphate salts. $\text{Ca}(\text{OH})_2$ did manage to control mildew satisfactorily in the glasshouse trials, however the treated leaves became white after application and it was decided not to test this product further since it did not convey the 'green' essence of organic production.

In the UK, environmental conditions are very conducive to scab and mildew development. This was represented by the high disease pressure (inoculum) levels used in the experiments described in the methodology. The products tested were unfortunately not as effective as synthetic fungicides in controlling disease. Whilst these alternative plant protection products may have success in controlling disease in countries where disease pressure is lower, the efficacy of these products is likely to be worse in areas where disease risks are high, as in the UK. However, some success may be had with such products where resistant or tolerant varieties are grown (see objective 2) – although more research needs to be done to achieve a balance between varietal resistance and plant protection through use of spray products.

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

The work carried out testing a range of organically acceptable spray products for control of rosy apple aphid in both spring and autumn applications showed that control of the pest in spring, when aphids are protected in tightly curled leaves, is very difficult and that autumn applications are more effective. Although migration times of adult aphids returning to apple in the autumn can vary, work done during 2001-2005 suggested that sprays applied between early and mid October are most successful. This ensures that spray treatments have the potential to intercept winged females (which fly first), winged males, or both. A simple way of monitoring the migration of winged adults would be valuable and assist in the optimal timing of autumn sprays. Pheromone and suction traps are available for orchard monitoring, but it is extremely difficult to distinguish between the various strains of *Dysaphis* and other aphid species caught in the traps, since many other species also have autumn migratory phases.

The trials showed that, unfortunately, sprays of a wide range of organically permitted materials were mostly of only limited effectiveness, even when applied as multiple applications. Of the organically permitted materials evaluated for autumn control, pyrethrum was the most effective, but results were somewhat variable. It is necessary to apply several sprays of pyrethrum to reliably get a reasonably high standard of aphid control, possibly because the persistence of pyrethrum is very short. As a result of this work, pyrethrum has now been approved for use on apple in the UK (available as Py Insect Killer) to target both rosy apple aphid and apple blossom weevil. As a purely contact insecticide, best results are achieved with high volume sprays designed to directly intercept the maximum proportion of the aphid population. Complete control of aphid populations was achieved through the use of conventional aphicides applied in the autumn (cypermethrin and pyrimicarb). Although of no consequence to organic growers, this result was of great interest to conventional growers who often struggle to control the pest using routine sprays during spring.

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