The State of Apple Orcharding

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A review of cider orcharding prepared in July-August 2009 for Heineken UK. This desk study summarises established best practices from both cider and dessert orchards, provides examples of the latest developments in horticultural research and considers alternative production systems that aim to reduce or eliminate chemical inputs and improve the financial, social and environmental sustainability of apple growing. The result is a snapshot of the state of orcharding in 2009.

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The state of apple orcharding 2009

With introduction to the key nutrient cycles

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Best practice

Basics and best practice for commercial apple orcharding

"Growers need to produce regular and heavy crops using a system which minimises environmental risks, complies with all food safety issues, conforms to all current legislation, minimises hazards to workers and third parties, but still provides the customer with the product they require."

Growing cider apples: a guide to good practice, 2002

Summary

Established best practices for the main aspects of commercial orchard management are outlined here. One factor that is seldom discussed in literature is the choice of machinery for mowing, spraying, harvesting, and pruning.

The style of management that is represented here is intensive and focuses mostly on yield optimisation, with some attention to minimisation of environmental degradation. Growers operate within two major constraints: price/tonne and yield/hectare.

Techniques from both cider apple and dessert apple growing are described, due to the prevalence of research and literature pertaining to the latter. Generally, practices oriented towards creating the quality standards required for marketable dessert apples are not included.

Best practices from both the UK and abroad are included, despite the differing conditions depending on location. This means that some practices will be of less relevance for UK production as they may pertain to a higher or lower cost model. Cost model generally depends on the cost of land purchase, land rent, labour costs, material costs and climate, which all vary country by country.

Choice of cultivars and rootstocks

Cultivars and rootstocks should be selected according to marketing considerations (i.e. bitterness, sharpness and sweetness) as well as site conditions, specfically;

- The cultivar gives the apple its **character**, so should be chosen for **marketing purposes**.
- The roostock gives the tree its **structure**, so should be chosen **as per site conditions**.

Different rootstocks and cultivars interact with each other in unique ways and some combinations should be avoided.

Choice of rootstock is a major factor influencing:

- tree size
- date of bloom (flowering)
- precocity
- winter hardiness (not so much in the UK)
- resistance to diseases
- presence of phytophthora (soil fungus)
- ground conditions
- soil quality and depth

- compatibility with the scion variety
- waterlogging and drought tolerance

Higher density planting works better with more **compact tree/rootstock combinations**, whereas **lower density planting** is better with more **vigourous trees**.

In the USA, "Club" or "controlled supply" cultivars of dessert apples have been established to control oversupply in the market and enhance the dollar return to the grower. (NB. In the US, cider is called 'hard' cider.) These restrictions can take multiple forms:

- Cultivars are **restricted geographically** by only allowing certain areas to grow the fruit
- Cultivars are **restricted by marketing constraints** where the fruit must meet a minimum quality standard to be labelled
- Cultivars are **restricted by** only allowing a certain **number** of trees to be propagated

For more information on Club cultivars, see the Pennsylvania Tree Fruit Poduction Guide, chapter on apples, at the following URL: http://tfpg.cas.psu.edu/.

Scab resistant dessert apple cultivars are bred in the Czech Republic, Italy, France, and Latvia and used worldwide. The wide adoption of scab-resistant cultivars is limited by the fact that most only carry the Vf gene for resistance and therefore, in solid plantings, the resistance can be broken down and spraying is usually necessary to some degree.

Site preparation and design

Location

Site location is a major component of success, both economically and environmentally. Depending on the type of apple grown, sites must be of a certain size to hit **commercial economies of scale** (e.g. it is generally felt that farmers not in a cooperative arrangement would require at least 50 acres for cider varieties for the UK market). **Ex-pasture or uncultivated** grassland is more **favourable** than long term ex-arable land or re-planting old orchards, as the soil structure tends to be better.

Additional major environmental considerations when chosing a site are:

- Site aspect (south facing is ideal)
- Slope (a gentle slope helps drainage and reduces frost pockets)
- Climate (low light levels limit growth in high lattitudes whereas poor rainfall limits growth in lower latitudes)
- Humidity
- Soil type and depth (deep sandy loam is good)
- Soil fertility and structure
- Prevoius cropping history of the land
- Drainage
- Proximity to residential buildings (close proximity is unfavourable for spraying purposes)
- Access to main farm buildings

Preparation

Site preparation at least **two years prior to planting** is essential because the trees will be in situ for several years and correcting **drainage and soil pH** is much more difficult at a later date. Other preparatory measures include erecting vermin-proof fencing and wind barriers and installing permanent underground draining systems where drainage is poor.

Planting

Density and design of planting depends on a wide range of environmental, economic and financial factors, specifically; the rootstock/variety combination, land purchase or rent price, labour price, degree of mechanisation desired, cost of trees, ties and stakes, proportion of suitable land on farm and bank interest rates. Ultimately, opitmal plant spacing reflects a **balance between the high-density, light penetration and sufficient alley space** for machinery to pass.

The question for most commercial growers is not *whether to plant densely, but how densley to plant*; for commercial **dessert apples** density ranges from **1250 to as high as 5000 trees per hectare**, whereas cider apples on Bulmers' own orchards are planted at **650-750 trees per hectare**. Dessert apples can be planted more densely as they are hand-picked so trees need to be sort and alleyways can be much narrower.

One of the main purposes of high-density plantings is to achieve early production. However, different spacing and arrangements suit different site conditions and degrees of tree vigour. Furthermore, spacing that is too narrow will require greater labour inputs, particularly with pruning and individual tree management.

The medium-density central leader orchard system (typical UK bush cider orchards)

The central leader system is the **dominant system used for cider apple production in the UK**; the fashion in the last 40 years has gone from 450 trees per hectare to 750, which has shifted as the financial climate and developments in orcharding have changed.

The trees in a central leader system should reach the maximum practical tree height as quickly as possible after planting, whilst still maintaining stability and erect growth habit. Branches eminate from one dominant 'central leader' branch and are trained and pruned to grow in a spiral pattern at 40-90 degree angles around the central leader. Even so, the system requires minimal pruning, with greater **emphasis placed on formative pruning** (in the early years) to **maintain dominance of the central leader**, which in turn controls the vigour of the trees.

Thus, pruning aims to **thin-out** the branch framework, which gives the grower the ability to produce **apples of an acceptable size** for machine harvesting (although size in iteslf is not important for the cider apple grower). Thinning-out also achieves good **spray penetration**, together with allowing **sufficient light for return fruit bud formation**. The severity of branch thinning and the length at which branches are shortened or completely removed will be governed by the trees spacing within the row and the allweyway width chosen.

The central leader system is most more adaptable to less favourable or atypical environmental conditions (particularly areas of high light intensity and long daylight hours) and socio-economic climates.

High-density orchard systems (slender spindle, trellis, french *axe* etc)

Not found in cider orcharding in the UK, only dessert and culinary. Instead of a large, strong framework, a weaker-framed tree is desirable as tree height needs to be limited for hand-picking; tree row widths may be narrower to compensate. Furthermore, support systems are needed throughout the tree's life for most dwarfing/rootstock variety combinations (post, conduit or trellis).

Planting in beds

Multi-row beds are **common for dessert production** in some areas, but much less common in cider apple production. The system is a way of achieving high density planting is by planting in 2, 3 or 5 bed rows. Staggered trees in multi-row beds give more space for each tree within the rows as alleyway space is sacrificed instead of row space. Significantly more trees may be planted per hectare in bed systems.

However, certain problems are associated with planting in beds, especially in cider orchards, due to the use of mechanical harvesting and the relatively large size of trees, which prevents the use of tunnel sprayers. Problems include:

- achieving good **penetration of sprays is difficult**, so the middle row is more susceptible to pests and disease
- **restricted access** to the trees **for pruning and harvesting**
- **light distribution around** the canopy can be **restricted**

Alleyways

Alleyways are fundamental to cider apple orchards that are mechanically harvested and must be established well before they are used by machinery. Their main purpose is for **machinery access**, but also to **limit weed incursion** (see sward management) and as a **harvesting surface** for shaken and blown or paddled fruit. Dessert and culinary growers do not cultivate grass alleyways as they do not harvest mechincally.

Fertilisation

Great importance is given to **pre-planting soil analysis and correction**, after which the nutrient profile of the soil can be corrected by ploughing down fertiliser dressings. Surface applications do not suffice unless the soil is already in top condition. For **large applications the dressing is split**, with some ploughed in and the balance incorporated during cultivations. After planting, the nutrients can be maintained by applications of granular fertiliser and foliar applications, particularly with trace elements.

In the Bulmers orchards, fertiliser is not a major cost of production as it is only applied in a band; phosphorus is expensive but not much is needed and, although potassium is essential and fairly expensive, it is readily available. The amounts of fertiliser used in young orchards is small in comparison to many other crops, and little fertiliser need be wasted so long as it is applied in split doses to the root zone of the trees (i.e. in bands).

Irrigation

Although irrigation is not yet common in UK cider orchards, a growing number of commercial farmers are trialling irrigation to relieve tree stress at critical times in the growing season. The results of the trials are not yet available, but irrigation elsewhere is generally successful, albeit expensive and potentially high risk in terms of nutrient leaching.

Pruning and training of trees

Pruning is meant to determine **how and when the tree will fruit** throughout the tree's life; a major challenge for cider apple growers is to control biennial bearing through good pruning (together with good general management). Pruning and training usually aim to produce the most effective tree shape for maximising light distribution, whilst considering other factors, including;

- Achieving the mature tree height as soon as possible
- Preventing biennial cropping by stimulating the production of growth out of phase with the rest of the trees growing and cropping pattern
- Ensuring a good crop of apples, in balance with the tree vigour
  - Observe optimum load for trees and prune to achieve correct apple load
  - Ensure correct level of vigor and removing shoots from base if too much vigor

Although seldom seen as a key consideration, tree health in terms of susceptibility to disease is also affected by pruning (as well as planting density). The more closely packed the branches are, the more moisture will be retained on the leaves and bark, leading to conditions that favour the development of diseases such as scab and mildew.

Training determines the plant’s outline, branching and frameworkand is particularly important in the first 4-5 years.
Early years pruning aims to maintain a balance between cropping and new growth, whereas later (declining) years pruning might be aimed to rejuvenate ideal tree vigour whilst still allowing light to penetrate the canopy.
Cuts tend to concentrate on removal of the whole branches (thinning) due to high labour costs.

Tools used include secateurs, saws, hand saws, extendable saws, chain saws and pole chain saws. In addition to pruning and training, growth inhibitors are used to achieve a better balance of vigour and precocity (e.g. Regalis and Cultar). Chemical thinners such as ThinsecTM were used in the past but have now been banned.

Different tree formats

Espalier (hedge format- intensive- no longer used much)
Standard and half standards (trunk 2m and 1.5m, respectively, widely spaced, long establishment period, 30-100 trees/ha)
Bush (trunk ~0.75m, semi-vigorous clonal rootstock, reduced canopy volume, easier to manage, more trees and thus higher yield, per hectare- 650-750 trees/ha); a central leader with side braches creates a conical tree in an A-shaped row)
Spindlebush (inc. free spindle, layer spindle, slender spindle and Noord Holland spindle); advantages include:

- Early cropping
- Can be planted very densely (1250-5000 trees/ha)
- Allow good light penetration
- Reduced pruning per tree but many trees per hectare

Though not used for cider orcharding in the UK, spindle trees on dwarf rootstocks are replacing older plantations for commercial dessert orcharding in Western Europe. The reason that they are not used in cider orchards is that the slender trees cannot withstand mechanical harvest.

Sward management, mowing and grazing

Ideally, alleys should not be cultivated from existing sward but should be **prepared and planted from scratch** with a specific mix of varieties; e.g. dwarfing rye grass, fescue and bent mixtures. Characteristics essential to the sward are;

- quick to establish
- easy to manage
- wear resistant
- dense and even cover
- low vigour to reduce mowings

Regular mowing (~8 runs/yr) is preferable, as emptying cuttings is not efficient for diesel use.

Intercropping in the sward is not generally recommended for commerical growers as it can compromise essential operations, cause rutting and compaction and create residual weed problems. Also, spray regimes may not be compatible. However, crops that can be intercropped include blackcurrants, strawberries, potatoes, maize, and daffodils. Some of Bulmers' contracted growers tried intercropping corn, flax, linseed and silage; none of the trials were viewed as being successful. Of the four crops, silage was the best performing, but:

- Silage requires a leafy, green, fast-growing grass
- Orchards require a dense, slow-growing, fine leaf lawn

However, minor losses in yield or yield quality may be accounted for by the financial return on silage or crop.

Grazing is generally be limited to standard orchards so that apple trees are not grazed. Livestock should be removed at least 56 days prior to harvest to avoid faecal contamination (most manufactures require this in the supplier contract). Chickens, ducks, turkeys, sheep, cows and pigs are all grazed in apple orchards, however they are rarely grazed by commercial apple growers. Livestock are costly as they are labour-intensive to rear and incur vetinary bills.

Controlling weeds

In the early years the **alley sward** should be **limited to a strip and not extend under the canopy** as the grass will compete with the trees for moisture and nutrients, thus reduce their productivity. Chemical or mechanical control methods are necessary for maintaining the weed-free strip of soil up to 2m wide along tree rows in order to restrict competition for water and nutrients, especially in the trees' early years. Applications of broad spectrum chemical **herbicide spray**, e.g. Roundup, **can be used to maintain the strip**.

Alternatively, black plastic **mulches** or organic mulches of straw, pomace or other agricultural materials **can be used** to the same effect, but can have disadvantages, e.g. harbouring pests and/or distorting the soil nutrient profile.

Another option is to cultivate plants with minimal demand for water and nutrients which can prevent penetration by more pernicious weeds (e.g. ground ivy, white clover, sedum etc.). However, surface cultivations are often viewed as impractical because they can damage soil structure, increase the risk of storage rots, decrease water content of the soil and are difficult to control which is important for ease when harvesting.

As the trees mature, grass and some weeds may be allowed to encroach onto the strip where they will buffet apples falling from the trees at harvest and reduce storage rots. Targeted herbicides may be used to control difficult perennial and annual weeds in the sward and tree row.

Frost protection

The most popular cider apple species are late-flowering in comparison to dessert species and therefore frost damage is not a major consideration for cider apple producers. To protect against frost, the architecture of the orchard can be designed to ensure frost pockets don't develop:

- Gaps for frost to escape from
- Slight slope for frost to 'drain away'
- Avoid tall hedges at the bottom of low-lying ground

Polytunnels and other protective barriers are not generally used in the UK due to negative impacts on flowering and the costs of covering and uncovering. Sprinklers and drips are also sometimes used to moisten trees although not much in cider production owing to the high cost of such treatment.

Pollination

Pollinators **must be present in the orchard and be active at bloom**. The most important pollinators are bees, however feral honey bee colonies are now nearly nonexistent in many areas due to the introduction of parasitic mites, and beekeepers are losing large numbers of colonies to these mites and the diseases they transmit. Solitary bees (i.e. masonry bees) can also be used as managed pollinators.

Many cider apple varieties are self fertile, but some are not, meaning that they require a pollinating species. A pollinating species is the source of pollen necessary to set fruit; it might be another tree with compatible pollen or a bouquet of flowering branches (same as the crops) placed in the orchard

Tips

- Provide other species to attract and feed bees, e.g. banks of wildflowers
- Ensure that bees are introduced at the right time if bought in from elsewhere
- Ensure sward crops do not flower at the same time as apple trees (to avoid competing with apple-blossom for bees)
- Weed blossoms, such as dandelions, mustard, and wild radish, should not be present in quantity since they attract bees away from fruit tree blossoms and insecticides regimes required may harm bee health
- Ensure that wind levels are low by providing wind breaks; but there must be some circulation of air to assist wind dispersal of pollen (and reduces the risk of scab infection)
- Ensure that a pollinating species is located not more than 100 feet from the variety to be pollinated

Disease and pest management

Basics

Knowledge of pests and diseases is critical and a high level of orchard management, including ensurance of an open tree canopy, is the best defence. Regular assessment of disease and pest levels and recording of activities is part of good mangement. Use of resistant/low susceptibility varieties is also a major strategy for disease and pest reduction.

The main disease problems that cider apple growers are likely to encounter include:

- Canker
- Collar rot and crown rot (phythophthora)
- Fireblight
- Mildew
- Scab
- Silver leaf

Some of the main insect pests of apple trees are:

- Aphids (e.g. Rosy apple and Woolly)
- Capsids
- Caterpillars
- Mites (e.g. Rust and Red Spider)
- Midges
- Moths (e.g. Codling and Tortrix)
- Apple Sawfly
- Blossom weevils etc.

Chemical control

Fungicides and insecticides used to control the main pests and diseases make up the largest economic input to the orchard; the typical regime for Bulmers orchards is 6-8 fungicide applications/yr plus 1-2 insecticide applications (sometimes in mixture). Pesticides are mostly sprayed but may also be applied as paints, slurries and soil drenches. Considerations for spraying include;

- Spray machinery must be well maintained to minimise waste by inadequate cover, which results in poor pest control
- Sprays must be chosen carefully according to patterns of resistance built up in disease and pests
- Pesticides can be broadcast using air-blast sprayers, or else a tunnel sprayer can be used (tunnel spraying is not favoured for cider production due to the requirement for smaller tree size and closer planting to fit into the sprayer)

The exact chemicals used change regularly depending upon legislation changes (prohibiting or restricting use), cost of chemicals, patterns of resistance and other factors. The chemicals commonly used in Bulmers orchards are as follows:

Chemical	Active Ingredient
Alpha Captan 80 WG	Captan
Indar (early season)	Fenbuconazole in Cyclohexanone
Radspor – Syllit	Dodine
Systhane – Albaugh Robut	Myclobutanil & Cyclohexanone

○ Topas – Topenco	Penconazole
○ Alpha Chlorpyrifos	Chlorpyrifos
○ CT Prilled Urea	Urea (foliar applied nutrients)
○ Potassium Nitrate	N, K_2O (foliar applied nutrients)
○ Round-up	Glyphosate

Mechanical control

For disease prevention, trees should be grown on well-drained soils and spaced and trained to allow sufficient air flow, , as dampness and stagnant, humid air encourages disease spread. Excessive 'sappy' growth should be controlled as this also encourages infection. Disease in nearby host varieties, such as hawthorn and rowan, should be cut-out or cot-off at the base and burnt before establishment of the orchard and during its lifetime. Grubbing-up of hedgerows is often not permitted by law.

Once a disease is present, 'cutting-out' of non-extensive infections from the tree is effective for some diseases (for example, mildew and fireblight). Pruning knives and saws used should be disinfected after each cut.

Biological control

The best pest targets for biological control in tree fruits are generally the secondary foliage-feeding pests that do not cause direct fruit injury (i.e., mites, aphids, and leafminers). Populations of pests that feed directly on the fruit (i.e. codling moth, Oriental fruit moth, and plum curculio) generally cannot be tolerated at levels high enough for special biological control agents to reproduce and maintain a stable population

There are four types of biocontrol agents:

- predators (eat prey)
- parasitoids (kill hosts)
- parasites (do not kill hosts)
- pathogens (i.e. diseases)

Pathogenic control agents may be applied to the trees in a spray; as such they are referred to as 'biopesticides'.

Predators

The biological control potential of the vast majority of beneficial arthropods is not realized unless:

- the pest develop resistance to pesticides,
- no pesticides are used, or
- only pesticides that are selective and nontoxic to these arthropods are used

Orchard predatory mites, common earwig, parasitic wasps, hoverflies and predatory flower bugs should all be encouraged and protected from pesticides. Methods to encourage them are:

- Planting of annual and perennial flowering plants and grasses in the inter-row sward and around the edge of the orchard provides alternative food sources
- Artificial refuges in apple trees also encourages them
- Some predators should be introduced, e.g. earwigs

The most successful biological control programmes for tree fruit crops involve mite predators of mite pests, inc. the european red mite and spider mite. The use of pheromone mating disruption, horticultural oils, and some of the more selective reduced-risk insecticides and miticides will allow a natural increase of predators capable of regulating pest mite populations to tolerable levels without the use of miticides. The aphid midge often contributes to biological control of spirea and green aphids in pome fruits, feeding on many species of aphids on many types of crops and have developed some resistance to organophosphate insecticides. However, they are susceptible to carbamates, pyrethroids, neonicotinoid, and certain miticides.

Ladybird beetles are also effective biocontrol agents for aphids and some mites, moth eggs, scales and mealy bugs; as are Lacewings, whose larvae (called aphid lions) are generalist predators of mites, thrips, soft scales, and almost any other soft-bodied prey, eating 100 to 600 aphids during a 1 to 2 week development period. Other important predators include minute pirate bugs, syrphid flies, ground beetles and rove beetles.

Parasitoids

Important parasitoids include;

- the tiny wasps (Aphelinus mali) that develop inside wooly apple aphids,
- tachinid flies that develop inside leafrollers, and
- ~120,000 species of Braconid and Ichneumon wasps that attack tufted apple bud moths and control many species of leafroller.

All species of Brachonid and Ichneumon wasps appear to be very susceptible to pesticides and are important only in pheromone disruption or orchards with minimal pesticide sprays. Trichogramma is another small wasp species that can be used to control several species of leafrollers, codling moth, and oriental fruit moth; it too is very susceptible to pesticides.

Control of apple scab

Successful control combines the use of cultural control and disease warning systems (such as AdemTM) and reduces fungicide use. Scab overwinters mostly in leaf trash on the orchard floor (and wet leaves are essential for infection to take place), but also on the tree in the wood and buds, so it is possible to control overwintering mechanically by:

- Applying 5% urea as a spray to leaf trash
- Flail mowing of the leaf litter on the orchard floor
- Pruning out scab on wood and buds in winter
- Maintaining good air circulation around the orchard and within the canopy

The use of scab resistant varieties makes the biggest impact overall.

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Latest developments

Some of the latest developments for orcharding globally

"There is no perfect production system. You need to develop your own style and a production system that suits your abilities, growing conditions, and chosen cultivars."

Pennsylvania Tree Fruit Production Guide 2008–2009

Summary

To the best of the researchers current knowledge, most academic work on commercial orcharding is very specific and reflects the mechanistic paradigm that dominates the biological sciences and agronomy. In contrast, little of the research to date has taken a more holistic approach. For example, there is no evidence of research that views the orchard as an ecosystem. This makes it hard to assess the ecological sustainability of commercial orchards.

Nonetheless, the research presented below provides a toolkit of options available to growers seeking to reduce inputs and improve sustainability. Each entry summarises a piece of research that has been chosen to reflect the latest developments in a particular area of orchard management. Two new products are also described. The research presented is not by any means exhaustive of the work undertaken in the field to date, but is the result of a quick exploratory review.

One very promising piece of research gives evidence that cultural controls and biocontrols for overwintering scab and leafminer can reduce levels of both by more than 90% (which is better than the reductions achieved by using conventional fungicide) – see below.

Disease warning systems

Disease warning systems can be used to reduce the frequency of pest applications for controlling scab and mildew (routine apps every 7-14 days is common for dessert orchards). The AdemTM (Apple Diseases East Malling) system is a PC-based system that warns of infestation risks so that sprays can be applied curatively instead of routinely. It uses epidemiological models that have been validated under field conditions to relate the development of scab and mildew to biotic and abiotic factors. The control of mildew is improved by using Adem and less fungicide is used this way. With scab, using Adem is not sufficient on its own, but it does improve control and lessen fungicide use if used in combination with other pest and disease control measures.

A M Berrie and X M Xu (2003) Managing apple scab (Venturia inaequalis) and powdery mildew (Podosphaera leucotricha) using AdemTM. Taylor & Francis Ltd.

Scab resistant cultivars

Evidence for the effectiveness of using scab resistant cultivars with minimal lime- and wettable-sulphur sprays

"The first crop of organically grown Australian-bred scab resistant apples (Malus × domestica Borkh. 'RS103-130') has been produced at an experimental site in Queensland, Australia. With minimal lime sulphur and wettable sulphur sprays, no apple scab has occurred on leaves or fruit. Fruit set at the site is excellent and has necessitated some hand thinning." For reaults, see the table below which is taken from the original research paper. The cultivar 'Galaxy' is not resistant to scab. Notice that in both years RS103-130 crops show no incidence of scab, although the trees were exposed to the disease.

Table 4. Pest and disease incidence (% of fruit numbers damaged) in the first two crops of organically produced of 'RS103-130' and 'Galaxy'.

Pest/disease	2005		2006	
	Galaxy	RS103-130	Galaxy	RS103-130
LBAM	27.2	49.6	6.4	1.9
Native Budworm	25.5	18.4	59.5	32.7
Qld Fruit Fly	5.9	4.9	7.8	3.2
Apple Scab	4.6	0.0	1.1	0.0
Glomerella	0.7	0.6	1.0	0.5
Alternaria	0.5	2.3	1.3	0.0
Codling Moth	0.4	0.8	0.2	0.3
No Damage			14.9	49.2

S G MIDDLETON ET AL (2007) ORGANIC PRODUCTION OF A NEW AUSTRALIAN-BRED SCAB RESISTANT APPLE IN QUEENSLAND, AUSTRALIA. .

Potential to reduce costs by using scab resistant varieties

The use of scab resistant cultivars for dessert apple growing can significantly reduce total variable costs. For systems using inorganic (copper and sulphur) sprays, costs can be reduced by 50% if a scab resistant cultivar is grown; whereas, for systems using conventional (biological fungicide) sprays, costs can be reduced by as much as 75%. The study compared costs incurred on a plot of trees with the scab-resistant 'Liberty' cultivar, to costs incurred on a plot of trees with the susceptible 'McIntosh' cultivar. The large differences in costs were due to the use of sprays on the McIntosh plots.

M A ELLIS ET AL (1998) EFFECTS OF AN APPLE SCAB-RESISTANT CULTIVAR ON USE PATTERNS OF INORGANIC AND ORGANIC FUNGICIDES AND ECONOMICS OF DISEASE CONTROL. ST PAUL: THE AMERICAN PHYTOPATHOLOGICAL SOCIETY.

Disease and pest management

Comparison of conventional spray, IPM and Biocontrol-only regimes for dessert apples showed IPM is most cost effective and Biocontrol-only, the least

Conventional, IPM and Biocontrol methods of pest management were trialled experimentally in New Zealand to compare effectiveness. The conventional system was very effective at eliminating pests in the short term, but created resistance of some species in the longer term. The IPM system was the most cost effective and performed well relative to the conventional programme. In the biocontrol-only system, the lack of effective controls for key quarantine pests limited economic sustainability and largely restricted production to the local market. The future of this system for export production depends on innovative technology to overcome these problems.

D.M. SUCKLING, J.T.S. WALKER AND C.H. WEARING (1999) ECOLOGICAL IMPACT OF THREE PEST MANAGEMENT SYSTEMS IN NEW ZEALAND APPLE ORCHARDS. ELSEVIER SCIENCE BV.

Evidence that cultural controls and biocontrols for overwintering scab and leafminer can reduce levels of both by more than 90%

Five different treatments were applied to fallen leaves to eliminate overwintering scab and leafminer. They included leaf shredding, 5% urea application, Microsphaeropsis ochracea application, Athelia bombacina application, and a control. The levels of ascospores were significantly reduced by all the methods below the level of the control. The most effective single treatment was urea, followed by leaf shredding. However, the best results are achieved by combining treatments i.e. shredding and M. ochracea or shredding and urea, which can achieve 90+% reduction.

CHARLES VINCENT, BENOIT RANCOURT, ODILE CARISSE (2004) APPLE LEAF SHREDDING AS A NON-CHEMICAL TOOL TO MANAGE APPLE SCAB AND SPOTTED TENTIFORM LEAFMINER. ELSEVIER SCIENCE BV.

Evidence that "Surround" for apple growers can reduce damage by Plum Curculio by 90-100% from controls

A relatively new product called "Surround," developed by the Engelhard Corporation, is made from specially milled kaolin clay, plus a spreader-sticker that disperses the clay over the foliage and holds it there. The idea is to "turn the trees white" by covering them with a thin layer of clay during the period from pink to four weeks after petal fall. Evidently, the clay covering does not negatively affect the trees by reducing photosynthesis. Cornell University, USDA, and grower trials have shown dramatic decreases in Curculio damage when the Surround product is used, often 90-100% less damage than controls, which is far better than the organic pesticide rotenone achieves. About 50 lb/acre of clay is used per spray, at a cost of around $25 in the USA. Surround is not effective against many other apple pests (although it may help protect against Apple Sawfly). *Plum Curculio is only native to the USA and Canada, but may have a relative in Europe that would respond to the treatment [Ed].*

BRIAN CALDWELL (NO DATE) "SURROUND" FOR APPLE GROWERS. TIOGA COUNTY: CORNELL COOPERATIVE EXTENSION.

Evidence for the effectieness of using SIRs to control scab- but only when applied at 3 or more growth stages. Still not as effective as fungicide

The study assesses the efficacy for scab protection on apple and pear orchards of three commercially available systemic inducing resistance (SIR) products, Messenger (a.i. Harpin protein), Phoenix (a.i. Potassium phosphite) and Rigel (a.i. Salicylic acid derivative) against a conventional fungicide (pencanazole). Little efficacy was demonstrated when the SIRs were applied at only 2 growth stages, but when applied at 3 or more growth stages, the efficacy was good (yet not as good as the conventional fungicide). The paper recommends that these SIRs can be used as an additional tool, but it doesn't recommend replacing conventional fungicides. *There may be potential to use these SIRs in combination with mechanical controls and other alternatives to conventional fungicides [Ed].*

GLYNN C. PERCIVAL, KELLY NOVISS AND IAN HAYNES (2009) FIELD EVALUATION OF SYSTEMIC INDUCING RESISTANCE CHEMICALS AT DIFFERENT GROWTH. ELSEVIER LTD.

Evidence that centrifugal training decreases development of aphids, mites and scab by increasing light distribution and canopy aeration

Most pruning systems for commercial orchards have been developed with the aim of maximising fruit yield. However, centrifugal training is an innovative new method of training apple trees in orchards with the aim of reducing the development of apple pests and diseases. It is being used in France and has been tested scientifically to measure impact on the development of aphids, mites and apple scab, in comparison to the 'original solaxe' system. The results show that, over three years, the centrifugally trained trees suffered significantly lower infestations of the most destructive species of aphids and spider mites, and up to 30% less scab in spring (but similar levels in summer). The system also increases fruit size and enhances fruit colour.

To prune centrifugally involves removing fruiting spurs from the trunk of the tree and branches during flowering (artificial extinction). It increases light distribution and canopy aeration, decreases humidity, alters growth dynamics and 'rhythmicity' affecting the development of foliar pests and pathogens, and decreases their spread through creating greater distances between branches.

S. SIMON ET AL (2006) DOES MANIPULATION OF FRUIT TREE ARCHITECTURE AFFECT THE DEVELOPMENT OF PESTS AND PATHOGENS? A CASE STUDY IN AN ORGANIC APPLE ORCHARD. ASHFORD: THE INVICTA PRESS.

The prospect for the use of nematodes and bacterial parasitoids to control insect pests is currently limited (1999)

Entomopathogenic nematodes have many attributes which favour them as biological control agents, however, their requirement for surface moisture for survival means that there are only remote prospects for using them as biological control agents for pests of apple and pear. In theory, the enormous advances in biotechnology and genetic engineering of the most important bacterial pathogen for biocontrol provide an unparalleled opportunity for the development of strains developed specifically for controlling orchard pests. However, in reality, the market for such products may be too limited to attract the interest of commercial companies willing to invest in the development of such products.

J V CROSS ET AL (1999) BIOCONTROL OF PESTS OF APPLES AND PEARS IN NORTHERN AND CENTRAL EUROPE: 1. MICROBIAL AGENTS AND NEMATODES. TAYLOR & FRANCIS LTD.

Orchard floor and management, soil and fertilisation

*Glenside's 'Integrated Soil Management Programme' claims to improve the natural productivity of growers' soils' and have a major beneficial impact on profitability **NB the information here is not from a peer reviewed source***

Glenside's 'Integrated Soil Management Programme' relies on the theory that, in order to improve productivity, soil should be treated as an ecosystem. Optimum production therefore requires a hospitable soil environment in which biological activity can flourish and operate effectively. Ideally 25% air for the microbes to breathe and fix nitrogen from, 25% water to drink and move around in, 45% mineral and 5% humus or colloidal organic matter. Glenside's diagnostic tool, The Glenside Albrecht® Soil Survey reports on:

- Soil Characteristics (Cation exchange capacity, Colloidal organic matter, Soil type)
- Trace elements (Boron, Iron, Manganese, Copper, Zinc, Molybdenum)
- Base saturation percentages (Calcium, Magnesium, Potassium, Sodium, Hydrogen & "others")
- Acidity/Alkalinity – pH
- Cation Surpluses/Deficits
- Desired and found values in kg/ha for the cations, Calcium, Magnesium, Potassium.
- Sodium, Sulphate and Estimated Nitrogen Release (ENR) Phosphate values in terms of found and desired in kg/ha.
- "Totals" – combined total of available and currently unavailable but exploitable soil reserves of Calcium, Magnesium, Phosphorus, Sulphur, Potassium and Sodium

HTTP://WWW.GLENSIDEGROUP.COM/CROPS/SURVEY_01.HTML

*Aston Horticulture's 'Tree Wash' claims to offer a cost effective method for reducing or eliminating chemical treatment **NB the information here is not from a peer reviewed source***

Tree Wash is a prophylactic, water-based, biodegradable product derived from garlic extract, seaweed and citrus. It is antifungal and antibacterial and contains more than 30 chemicals that stimulate plant growth. It also repels many insect pests, reduces drought-stress, increases storage life and has no known harmful effects on wildlife (including beneficial insects) or human health. Tree Wash can be diluted and applied as a spray every 14 days during the growing season.

HTTP://WWW.ASTONHORTICULTURE.COM/TREEWASH.HTM

Evidence that the use of compost in an orchard ecosystem is beneficial to management of weed, fungal, and insect pests

The effect of compost application on weed, fungal, and insect pest management in apple orchards was investigated from 1999 to 2001. Composted poultry manure was applied in June 1999 to half of two small research orchards which had previously received little or no management. This study showed that the use of compost in an orchard ecosystem is beneficial to management of weed, fungal, and insect pests. The use of compost as a mulch in orchard ecosystems should be encouraged as a sustainable management practice because of a potential to reduce pesticide use.

M.W. BROWN AND THOMAS TWORKOSKI (2004) PEST MANAGEMENT BENEFITS OF COMPOST MULCH IN APPLE ORCHARDS. ELSEVIER BV.

Evidence that plant growth regulators applied to alleys can suppress growth of sward enough to eliminate 1-3 mowings/year

Three plant growth regulators (MH, paclobutrazol and EPTC) applied to established grass driveways in an apple orchard suppressed growth of the ground cover sufficiently to eliminate one to three mowings.

STEPHEN S. MILLER AND B. JOE ELDRIDGE (1989) PLANT GROWTH REGULATORS SUPPRESS ESTABLISHED ORCHARD SOD AND DANDELION (TARAXACUM OFFICINALE) POPULATION. WEED SCIENCE SOCIETY OF AMERICA AND ALLEN PRESS.

Use of rootstocks tolerant to weed competition to overcome yield problems in organic and low-input systems

Problem: In organic and no-spray orchards, weed competition stunts development of trees in the first three years of growth and can significantly inhibit yield potential being reached later on.

Reasons: Organic growers normally use the same dwarfing rootstocks as conventional growers, but because organic weed control is much less 'clean', weed competition is a major problem for them. Attempts to use vigorous rootstocks are not commercially favourable as the trees produced are too large for intensive planting and take too long to produce fruit.

Solution: This study uses dwarfing rootstocks that are tolerant to weed competition, in combination with scab-resistant cultivars in a 100% organic system, and provides evidence that this approach can produce near-optimum yields and high quality fruit. 'Supporter 2' was the best performing rootstock for this purpose.

F P WEIBEL AND F SUTER (2008) IMPROVED ORGANIC AND LOW INPUT APPLE PRODUCTION USING ROOTSTOCKS TOLERANT TO WEED COMPETITION. ACTA HORTICULTURAE 772. ISHS.

Aluminium mulch improves yield and fruit quality over conventional mulches

Mulches are more favourable than chemical weed control due to the effects of herbicides on human and environmental health. They are also more favourable than mechanical methods due to the high cost of the latter. However, they can harbour rodents and insects that can damage trees. In this study, alternative Ground Cover Materials Systems (GCMS) were used to see if they had more favourable effects on fruit yield, quality and other aspects. Aluminium (foil sheet), bark and black propylene GCMS's were used. Aluminium had the most beneficial results, improving quality and yield in comparison with conventional mulches.

TAHIR, I., JOHANSSON, E. AND OLSSON, M. (2005) GROUNDCOVER MATERIALS IMPROVE QUALITY AND STORABILITY OF 'AROMA' APPLES. HORTSCIENCE 40 (5) ALEXANDRIA: AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE

Evidence that management of orchard floor and margins to foster build-up of beneficial predators also attracts more harmful pests

Although margins and orchard floors that are managed to foster build-up of beneficial natural enemies can lead to better control of some pests, population increases of numerous other important orchard pests are favoured by such practices.

R J PROKOPY (1994) INTEGRATION IN ORCHARD PEST AND HABITAT MANAGEMENT: A REVIEW. ELSEVIER SCIENCE BV.

Evidence that the use of cover crops to attract beneficial predators can actually have negative impacts by attracting more pests than predators.

A selection of suitable cover crops that have the potential to encourage more beneficial insect predators for biocontrol of pests were grown under controlled conditions in apple orchards in Victoria, Australia. They included Queen Anne’s lace Ammi majus/fennel Foeniculum vulgare (Apiaceae), chicory Cichorium intybus/yarrow Achillea millefolium (Asteraceae), white mustard Sinapis alba (Brassicaceae), buckwheat Fagopyrum esculentum (Polygonaceae) and fenugreek Trigonella foenum-graecum (Fabaceae). The crops did not attract any more beneficial predators than the control swards of grass, however they did attract more harmful pests, create russetting problems and impacting negatively on productivity of the crop in some areas.

N J BONE ET AL (2009) COVER CROPS IN VICTORIAN APPLE ORCHARDS- EFFECTS ON PRODUCTION NATURAL ENEMIES AND PESTS ACROSS A SEASON. ELSEVIER LTD.

60cm tall ‘babydoll’ sheep can be grazed beneath grapevines to reduce mowing; perhaps they could be used in mature bush orchards too?

A New Zealand winemaker has experimented with grazing babydolls, a rare breed of sheep which only reach about 60cm tall when fully grown, in his vineyards. Because the grapes tend only to start growing from about 110cm off the ground the sheep can't reach them. The farmer has tested 10 of the sheep on a 125-hectare patch of vines with satisfying results; they are effective grazers and have not caused any damage thus far. He hopes to build his stock to 10,000 within the next five years; if successful the flock should save him NZ$1.5m (£600,000) a year in diesel and he will sell the sheep for meat.

D. GRAHAM-ROWE (2009) “THE LOW-CARBON WINE BAA: WINEMAKER DEPLOYS MINIATURE SHEEP TO CUT FUEL COSTS AND KEEP GRASS SHORT”, GUARDIAN.CO.UK, WEDNESDAY 22 JULY 2009 12.55 BST.

Alternative Systems

Summary

This section details some alternative 'orchard paradigms' that have the common aim to reduce or eliminate inputs, foster diversity and increase environmental and social sustainability of orchards, whilst competing with conventional (intensive) growing methods in terms of safety, quality and economics. Some of the systems described rely only on the production of apples for their income (e.g. IFP, bottom-up IPM and organic), whereas others are more likely to rely on diversifying their income streams (e.g. silvoarable intercropping and traditional orcharding).

Integrated Fruit Production (IFP)

Integrated Fruit Production (IFP) claims to reduce environmental impact AND improve income

- Integrated Fruit Production (IFP) is a systems approach to fruit growing that aims to improve farm sustainability
- IFP's central objective is to replace polluting inputs for environmental benefit whilst taking into account farmer income, consumer and employee health and product quality
- In 1991 94% of swiss orchards were managed according to IFP guidelines, achieving similar incomes to non-IFP producers but with lower environmental impacts. IFP is certified by IP-Suisse
- The New Zealand pip-fruit industry has seen a rapid uptake of IFP production programmes over the last seven years; implementation has led to a 50 percent reduction in insecticide use and a 95 percent reduction in organophosphate insecticide use

Swiss IFP study

A recent study identified ecological-economic success criteria for sustainable orchard farming. Findings of the study:

- Among a sample of swiss IFP producers, their was no correlation between farm income and environmental impacts, therefore there was no trade-off between environmental performance and income using the IFP system
- Some farms that used less diesel and machinery per hectare than others also had higher incomes
- The two farms with the highest incomes per hour also used the least nitrogen fertiliser, fungicides and insecticides
- Seeking to maximise income per hour through IFP seemed to be an environmentally sound management goal
- High income farms invested more labour in pre-harvest activities (such as pruning) than low income farms, and also had higher, more stable outputs (yield and receipts/ha) than lower income farms

Belgian IFP study

The Belgian government recently decided to encourage integrated fruit production and examined the economical and environmental impacts of IFP against traditional (intensive) methods. The findings of the study:

- The total use of active ingredients of pesticides in the traditional production method of apples was one third higher than in the integrated production method
- No significant difference in profitability could be detected between the IFP and traditional orchards

New Zealand IFP study

Another recent study evaluated a pilot NZ IFP-P programme (which was commercially evaluated in the 1996-97 season) according to insecticide use, fruit quality and costs. Growers in the pilot were asked to follow the IFP pest management guidelines published in the ENZA NZ IFP-P Manual. Findings of the study:

- IFP orchards received fewer post-bloom insecticides with an average reduction of approximately 60% compared to conventional orchards, resulting in lower insecticide costs; however, this was substantially offset by loss of fruit value
- Although the programme produced fruit which was generally impressive for its freedom from pests, damage occurred in a few blocks at unacceptable levels (NB. This trial involved dessert fruit so may not be applicable)
- Potential benefits of reduced pesticide application costs and improved market access for IFP fruit was estimated to range from $150-250 per hectare in some orchards
- Feedback from growers indicated that many liked IFP because they considered its safety better for their family

In summary, the results of this study are not conclusive and may not be enough to convince growers to try IFP.

Best practices and core competancies needed for good IFP

- At the farm level:
    - A portfolio of orchards of different cultivars, different planting systems and different ages gives stability to overall yield by insuring against weather, disease and price fluctuations
    - An optimum cultivar mix
    - Long-term planning and careful decision-making relating to the amounts of labour inputs designated to different orchards in different years
- At the orchard level:
    - Awareness of former and future seasons vis-a-vis pest, disease, weather and other variable yield drivers
    - Strong knowledge of the dynamics of growth of different rootstocks and cultivars
    - Strong investment in pre-harvest pruning and training
- At the tree level:
    - Detailed knowledge and observation of feedback loops e.g. between fruit load and flower formation, negative impacts of agrochems, relationships between micro-orgs and arthropods etc
    - Precise timing and application of activities involving machinery and agrochem apps- and not compensating for bad orchard management by increasing inputs
- Overall, high competance in organisation is necessary for best environmental and economic success, including an ability to organise in a non-linear way, integrating growth curves and feedback loops with management decisions
- The best results are not achieved through lowering costs by reducing inputs, but through increasing yields with the same input intensity; this is because, whereas annuals respond strongly to input variation (ie. more N = more yield), tree crops are mainly output-driven, responding to feedback loops

P Mouron et al (2006) Life cycle management on Swiss fruit farms- Relating environmental and income indicators for apple-growing. Elsevier BV.

J. T. S. Walker et al (1997) INTEGRATED FRUIT PRODUCTION FOR NEW ZEALAND PIPFRUIT: EVALUATION OF PEST MANAGEMENT IN A PILOT PROGRAMME. Proceedings of the 50th New Zealand Plant Protection Conference. Hawkes Bay: New Zealand Plant Protection Scoiety.

D. Van Lierde and A. Van Den Bossche (2004) ECONOMICAL AND ENVIRONMENTAL ASPECTS OF INTEGRATED FRUIT PRODUCTION IN BELGIUM, in Acta Horticulturae 638: XXVI International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century

Bottom-up IPM

Bottom-up IPM can deliver highly successful control of all major pests

- Top-down IPM
    - Takes as its starting point a conventionally managed agricultural ecosystem that has been under commercial operation for several years or decades
    - Aims, in stepwise fashion, at reducing the total amount of external input and control imposed upon the system while gradually advancing the influence of natural ecological processes
- Bottom-up IPM
    - Takes as its starting point a nearly natural or not yet managed agricultural ecosystem
    - Aims to add external inputs only as needed and only in quantities necessary to augment natural ecological processes and overcome biological barriers to attaining a marketable product
    - This form of bottom-up IPM generally is consistent with the precepts of integrated fruit production (EU) and sustainable fruit production (USA)

Bottom-up IPM study

- This study of an orchard managed using a bottom-up IPM approach for 20 years shows clearly that such a minimum-intervention approach can be conducive to sustained production of high quality apples even under high pest pressure
- The high levels of pest-free fruit (92%, compared to an average 80% for commercial IPM managed orchards nearby) were achieved with annual application of one pre-bloom horticultural oil spray, two insecticide sprays and two fungicide sprays compared with an annual average of two pre-bloom horticultural oil sprays, one acaricide spray, seven sprays containing insecticide and nine sprays containing fungicide in the large commercial orchards
- Another difference was the substantially lower input of materials and higher input of labour for the bottom-up orchard

Design and management of the Bottom-up IPM orchard

- Small size; only 50 trees, all on dwarfing and semi-dwarfing rootstocks, bordered on two sides by woodland and two sides by fields
- Pruned annually in March and received lime and fertilizer based on annual soil pH and leaf nutrient analysis
- All 50 trees were scab-resistant cultivars and also largely resistant to powdery mildew, fire blight and cedar apple rust
- All unmanaged principal host trees of codling moth (apple, pear, hawthorn and quince) within 200m of the orchard perimeter were removed to create a host-free zone sufficiently broad to discourage immigration of codling moth females, lesser appleworms and several species of leafroller
- The proliferation and growth of plants in the same family as apples (but not including apples) was encouraged in the area adjacent to the orchard to support beneficial enemies of pests such as mites, leafminers, leafhoppers and aphids
- No attempt was made to manage orchard understory plants in a way conducive to buildup of beneficial arthropods
- Additional arthropod management strategies:
    - Scale and red spider mite: horticultural oil at 40l/ha was applied annually
    - Curculio, Sawfly, Green fruitworm, Codling moth, Lesser appleworm and Leafrollers: Phosmet at 4 kg/ha of formulated material was applied annually at or shortly after petal fall and again 10–17 days later
    - Apple maggot flies: unbaited red spheres, 8.5 cm diameter and coated with TangletrapTM were deployed each year at the rate of 1–3 per tree (according to fruit load) from early July through harvest (the device, about the size of a croquet ball, mimics the apples hanging beside it)
    - All pests: fallen apples were picked up and removed weekly from early or mid-August until harvest
- Additional disease management strategies:
    - Sooty blotch and flyspeck: the unsightly black blotches were removed by cleaning each apple with a damp cloth before packing it for sale; this eventually proved so laborious as to be uneconomical, so an application of captan at 4 kg/ha mixed with benomyl at 1 kg/ha was applied twice annually (perhaps not necessary with cider fruit as appearance does not affect value)
- Further practices are detailed in the paper referenced below (inc. vertebrate management and thinning)

R J Prokopy (2003) Two decades of bottom-up, ecologically based pest management in a small commercial apple orchard in Massachusetts. Elsevier Science BV.

Silvoarable intercropping and alley cropping

- Evidence suggests that modern silvoarable production systems can be very efficient in terms of resource use, making them environment-friendly and economically profitable
- Although the majority of existing systems use timber tree crops, some growers are using the silvoarable system for dessert and cider apple production
- Intercropping in apple orchards in northern Europe including the UK has a long history and wide historical distribution, but the current extent is limited by light levels which are often too low for commercial viability
- Professor Steve Newman is a recognised expert in this area of research, so the following is kept brief

Design basics

- Tree rows are spaced at a minimum of 10-14 m apart to allow enough room for cultivation operations
- Usually a whole number of cultivation equipment widths is chosen for efficient operations
- Rows are best aligned North-South and both single and double rows of crop trees can be used
- Weed control is paramount; black plastic mulches give good tree establishment and growth
- The most common intercrops for orchards are soft fruits (e.g. blackcurrant, raspberry) or vegetables (e.g. asparagus)

Benefits of silvoarable cultivation

- Crop quality and yields can be increased by enhancing microclimatic conditions, offsetting any reduction by the removal of tree strips from cultivation
- Utilisation and recycling of soil nutrients is improved
- Wildlife habitat and corridors are created
- The aesthetic diversity of silvoarable is an improvement to open mono-cropped areas with a truly innovative landscaping potential, and could improve the public image of farmers to society (especially in sparsely wooded areas)
- Silvoarable is favourable with the laws guiding agriculture and forestry and the directing principles of the Common Agricultural Policy

Silvoarable Agroforestry for Europe (SAFE)

A three-and-a-half year research project (August 2001- March 2005) managed by the Institut National de la Recherche Agronomique (INRA) in France and involving (among others) Cranfield University, investigated the long-term financial benefits and costs of different silvoarable systems. Accurate monitoring of trees and crops in various silvoarable systems was performed in experimental plots in France, England, Spain and Italy. The impact of tree density, tree size and tree pruning schemes on crops' productivity was analysed, quantified and modelled. The key findings:

- The average productivity of silvoarable systems is higher than the combined productivity of separate tree and crop systems; productivity increases of up to 30% in biomass and 60% in final products have been observed
- Tree-crop systems are able to capture more resources from the environment than pure crop or tree systems because competition induces adaptation and adaptation results in facilitation, a process that explains why mixed plots are significantly more productive than pure plots
- Using the SAFE biophysical and economic models, optimum management schemes can be derived for tree stand densities, spacing and orientation, tree species choice, intercrop rotation choice, and specific management techniques

Cherry trees intercropped with fodder beet, Germany

- Agroforestry plots are often as profitable as agricultural plots in no-grant scenarios
- Current policies totally prevent European farmers from adopting silvoarable agroforestry: in most cases, farmers will lose the crop payments and are not eligible for any subsidy to plant the trees, which is why at the moment agroforestry is artificially unattractive for European farmers (except for in France; legislation recently adapted)

ANON (1997) "SILVOARABLE – INTERCROPPING AND ALLEY CROPPING", IN AGROFORESTRY NEWS VOL 6, NUMBER 2:33. DARTINGTON: AGROFORESTRY RESEARCH TRUST.

DUPRAZ, C. ET AL (2005) SAFE FINAL REPORT: SYNTHESIS OF THE SAFE PROJECT (AUGUST 2001 – JANUARY 2005). MONTPELLIER: INRA.

EICHORN, M. P. ET AL (2006) SILVOARABLE SYSTEMS IN EUROPE – PAST, PRESENT AND FUTURE PROSPECTS, IN AGROFORESTRY SYSTEMS, VOL. 67. WARREN: SPRINGER.

Traditional orcharding

- In a traditional orchard, groups of standard and half-standard trees are grown on vigorous rootstocks planted at low densities on permanent grassland
- The trees are generally planted 8-10 metres apart
- Standard orchards are important habitats for mammals such as dormice, hares and bats; birds such as barn owls, woodpeckers, bullfinches, tree sparrows and thrushes; rare insects such as noble chafer and stag beetle; and plants such as mistletoe, as well as a range of lichens

Standard orchards and biodiversity

Orchard trees

- The individual trees are the most important wildlife habitat in the orchard
- Veteran trees and dead wood, standing or fallen, harbour a wide variety of decayed-wood insects and other invertebrates
- They also provide nesting and feeding opportunities for a diverse range of birds
- Dead and decaying wood should be retained wherever possible and only removed where it is diseased, unsafe or interferes with necessary operations
- Most orchard plants and animals depend on the maintenance of a full age-range of orchard trees; new trees may need to be planted to ensure this continuity

Orchard hedgerows

- Hedgerows, scrub and non-fruit trees on the boundaries of orchards or within them also add biodiversity value by providing shelter and food for wildlife
- Hedgerows should not be trimmed every year as this will reduce the crop of berries and flowers
- When they are trimmed, they should be cut slightly further out each time to avoid cutting into old wood
- In the long-term, hedges should be maintained through laying and coppicing in rotation

The orchard floor

- Grasslands in orchards can be rich in wildflowers such as wild daffodil and green winged orchids or, in cobnut plat, woodland plants like primrose and toothwort
- Colourful waxcap fungi are also found in orchard grasslands
- Bumblebees and other insects nest in areas of longer grass and in patches of bare ground
- Sward management should be tailored to the wildlife present but grazing should keep the sward height between 5 and 15 cm
- Hay cuts should be late enough to allow wildflowers to set seed, and areas of rough grass in corners and along hedges should be left ungrazed or unmown in rotation to provide wildlife habitats

NATURAL ENGLAND (2007) TRADITIONAL ORCHARDS: A SUMMARY: NATURAL ENGLAND TECHNICAL INFORMATION NOTE TIN012. SHEFFIELD: NATURAL ENGLAND.

Organic orcharding

Disease and pest management

- Successful organic apple production with conventional apple varieties is virtually impossible as scab control would require numerous applications of sulfur, lime-sulfur, or Bordeaux mixture (containing copper), thus putting an un-natural amount of these toxic chemicals into the orchard environment
- The solution is to grow scab resistant apple varieties; no fungicide sprays are required for scab control if scab resistant cultivars are used
- To be certain that the resistance is not overcome, all sources of scab such as unsprayed apple trees, wild apple trees or root suckers should be removed from the orchard and hedge rows
- Cultural control also helps lessen scab, i.e. dead apple leaves on the ground should be removed
- Raked leaves may be burned, buried or preferably composted under a layer of soil to prevent the escape of spores
- Earthworm activity and numbers should be encouraged because they will consume large quantities of apple leaves

Fertilisation

- The rapid development of new leaves, blossoms and young fruit early in the year may cause nitrogen stress on the tree signified by a pale green colour of the foliage
- Foliar applications of fish emulsion, 100 L in 3000 L of water per ha applied at early pink and 50 L in 3000 L water per ha at petal fall should supply enough nitrogen to relieve the stress
- Seaweed extracts have also been recommended for foliar application to relieve nutrient stress

Sward management

- A weed free strip can be accomplished with cultivation but care must be taken to avoid damaging shallow roots

- After three years a mulch can be used to stave off weeds, e.g. uncomposted conifer or oak bark chips and sawdust applied 10cm thick
- The sward should contain a mix of species, not limited to grasses, in order to encourage biological control agents
- Some plants which should be encouraged are yarrow, wild carrot, dill, carroway, catnip, mustards, blackeyed susans, goldenrod, buckwheat, nasturtiums, clover, a bit of alfalfa, and other native flowering species
- A good ground cover should be diverse and able to withstand some traffic in the orchard as well as at least one mowing in the autumn before harvest, if not more often
- Autumn mowing makes harvesting easier and helps owls and hawks capture mice and voles

Pruning and training

- Summer pruning is important in improving quality and storage life and involves the removal of some branches to open up the canopy to allow light penetration
- Hand thinning of fruit is very labour intensive but can be practical in small operations
- Experimental mechanical pruning is practiced in some places, e.g. high pressure water jets from guns with four nozzles have been attempted with some success
- Large ropes hung from a metal bar extended over the tree row from a hydraulically operated front end loader on a tractor has been used to remove blossoms from peach trees

P. G. Braun, R.F. Smith, J.M. Hardman, D.H. Webster, W. Craig, and R. Rogers (2004) ORGANIC APPLE PRODUCTION - Guide for Nova Scotia. Kentville: Nova Scotia Department of Agriculture and Marketing.

No-spray orcharding

Five general tips for no-spray orcharding

- Choose your varieties for disease resistance
- Prune trees yearly to allow good air passage through them; burn or otherwise dispose of all prunings to help prevent disease spread
- Remove untended alternate host trees within at least 100-200 yards of your planting if possible (esp. wild fruit trees, crabapples and hawthorns)
- Hand-thin all fruit within reach by three weeks after petal fall
- Pick up all harvest drops and windfalls and destroy

No-spray control of specific pests (most relevant in USA)

- Plum Curculio (USA and Canada):
  - Run chickens or guinea hens under the trees from petal fall to July 15; feed them corn meal under the trees; they will eat many of the "curcs"
  - Mow the grass very short in late June-early July and rake the small fallen "June drop" fruit into the sun or take them away; this will kill the developing larvae within the fallen fruit
- Codling moth:
  - In May, hang open gallon milk jugs in your trees with the following concoction: 1 cup molasses plus some yeast in 1 quart water; this is said to attract and drown some of the moths, and some apple maggots as well; pour out and renew in July
- Apple maggot (USA and Canada):
  - Be sure to pick up all harvest drops right away
  - On July 1, put red ball sticky traps in your trees (4 per standard, 2 per semi-dwarf, or one per dwarf)
  - Deer may help by eating fallen fruit from wild trees in the area, thus reducing apple maggot pressure
- Borers (USA only?):
  - Chickens will help against these, too
  - Wrap window screen around the bottom 24 inches of trunk in the spring as a barrier; tie at top, and cover with soil at bottom
  - Irrigate during dry spells, as drought stress makes trees more subject to borer attack
  - Keep weeds down around the trunk, and be sure to remove plastic rabbit guards during the growing season
  - Inspect your trees in September when new larvae are near the bark surface and destroy with a knife or wire

Brian Caldwell (No date) No-spray Fruit Growing in Home Orchard. Tioga County: Cornell Cooperative Extension.

Concluding remarks

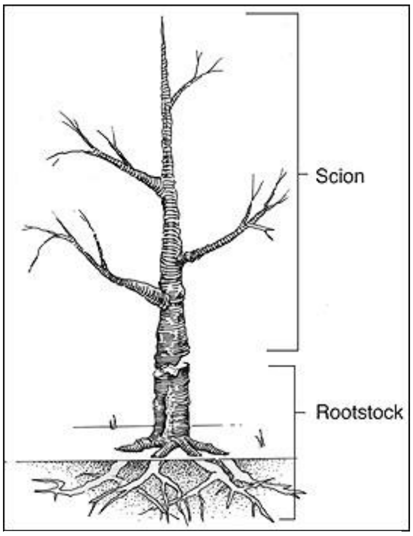
Apple growing is a diverse and evolving field. There are pioneers in approach working in the USA, Canada, Switzerland, France, New Zealand and Australia. The evolution of apple-growing research and practice is divergent, with specialists in intensive and highly technical solutions to yield optimisation on the one hand, and a range of alternative initiatives that are in search of lower impact and less spray-dependent solutions on the other.

Current research into apple growing technology and practice is predominantly dedicated to areas with the potential for immediate financial returns and is somewhat 'behind' emergent sustainability and systems-based scientific research and development. Pest control is a major area of research and although IPM is now commonly incorporated to orchard management, research funding is often delegated to development of new pesticides and disease resistant varieties for the purpose of planting more intensively without experiencing yield losses that result from spread of diseases, such as apple scab. On the converse, development of systemic approaches based on integration/application of constructed ecosystems to pest control is limited.

Intercropping and grazing of commercial apple orchards remains rare but increased uptake could be helped by initiation of joint enterprises, spreading the responsibility and risk between two parties and allowing each party to focus time and expertise on the enterprise they know best. It is clear from the research that the economics of such techniques has so far been little explored, with the major exception of the work at Cranfield University as part of the S.A.F.E. project.

Clearly, more research is needed. The current study presents a snap-shot review of contemporary and past apple growing techniques and is not a conclusive document but a working paper designed to stimulate thought and further exploration. Thus, key areas for further research will be published in an Appendix to this report and a second, updated version will be published next year.

Glossary



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Cultivar — A cultivar (also known as a 'scion') is a cultivated tree variety that is bred to give the apple its character.

Most trees grown in cider orchards are composed of two different varieties; the cultivar (or scion), and the rootstock (see diagram). Some trees may be composed of three varieties, cultivar, trunk stock and rootstock.

Dwarfing tree — A dwarfing tree is grown a rootstock that has low vigour, giving a short trunk and generally limiting the final size of the tree.

IFP — Integrated Fruit Production (IFP) is a system introduced to growers to lessen dependence on pesticides.

IPM — Integrated Pest Management is the control of pests, diseases and weeds at the point at which their predicted economic damage exceeds the cost of the management intervention (intervention threshold). IPM requires the monitoring or prediction of pest, disease and weed levels as well as the coordinated use with all available control methods, including cultural, biological, genetic and chemical methods.

Precocity — Precocity describes the age at which a tree first bears fruit.

Pip fruit — Pip fruit refers to only apples and pears.

Rootsock — A rootstock is a cultivated variety that is bred to give the tree its structure (see diagram).

Silvoarable — In silvoarable systems agricultural or horticultural crops are grown simultaneously with a long-term tree crop to provide annual income while the tree crop matures.

SIR — Systemic Inducing Resistence products

Sward — A sward is a particular mix of grasses and other ground cover plants.

Variety — A variety is a subdivision of a species having a distinct though often inconspicuous difference and breeding true to that difference.

Useful Websites

International Society for Horticultural Science (ISHS): http://www.ishs.org/

Pennsylvania: Tree Fruit Production Guide: http://tfpg.cas.psu.edu/default.htm

Silvoarable Forestry for Europe (SAFE): http://www.ensam.inra.fr/safe/

National Orchard Forum: http://www.nat-orchard-forum.org.uk/