Apples – conventional, IPM and organic

Despite the growth of integrated and organic apple production in Europe most apples are still produced using conventional methods. Pesticides with serious health and environmental hazards are used and the number of sprays per season is high. The result is high inputs costs, health risks and the presence of pesticide residues in apples, often exceeding the Maximum Residue Levels. Pesticide use reduction targets, along with requirement for farmers to follow crop specific integrated production guidelines are needed.

In 2005 11.96 million tonnes of apples were produced from 575,796 hectares (ha) in the 25 member states of the European Union[1]. This production was accompanied by high levels of pesticide use; only vineyards use more pesticide per hectare than fruit trees[2]. High pesticide use frequently results in residues in apples, and these often exceed Maximum Residue Levels (MRLs)[3]. Organic production, despite having none of these drawbacks, currently accounts for a very small percentage of total apple production.

Conventional production

Indicators of pesticide use on apples in Europe are hard to find. However, the UK government carries out regular surveys of pesticide use. In 2004 they surveyed pesticide use in orchards and fruit stores[4].

This survey revealed high levels of pesticide use. Over 90% of the area under apple production is sprayed with insecticides, fungicides and herbicides, and nearly 80% is treated with growth regulators. By contrast, biological control is used on only 0.1% of the area.

Apples received, on average, seventeen spray rounds, with 99.2% of the total area grown receiving at least one pesticide treatment. Thirteen fungicide sprays, five growth regulators, five insecticide sprays, two herbicides and a urea spray comprised the average treatment regime, with a total of 42 products used on average.

Table 1. Pesticide treatments of Cox apples, Great Britain

Chemical group	Treated area (%)
Acaricides	12.0
Biological control agents	0.1
Insecticides	94.0
Fungicides & pruning paints	97.0
Herbicides	91.8
Sulphur	12.1
Growth regulators	77.3
Tar oil/defoliants	6.2
Urea	28.4
Not treated	0.8

The five most extensively used fungicides were captan, myclobutanil, penconazole, carbendazim and dithianon. Myclobutanil and captan were sprayed on average five times during the season. The largest number of treatments were against mildew (*Podosphaera leucotricha*) 41%; scab (*Venturia inaequalis*) 38%; and canker (*Nectria galligena*) 9% of all treatments.

Insecticide usage was dominated by chlorpyrifos, methoxyfenozide, thiacloprid, fenoxycarb and triazamate. Chlorpyrifos was applied to almost 90% of the area of Cox dessert apples grown. The largest number of treatments were against codling moth (*Cydia pomonella*) 21%, and the rosy apple aphid (*Dysaphis plantaginea*).

Glyphosate was the main herbicide used, accounting for over a third of the volume of all herbicides, followed by dicamba/MCPA/mecoprop-P, diuron, 2,4-D and glufosinate-ammonium.

Paclobutrazol (58%) and gibberellins (42%) accounted for most growth regulator usage. Paclobutrazol was used for growth regulation while gibberellins were mainly used to improve skin finish and fruit set.

Many of the approved pesticides are moderately hazardous regarding their acute toxicity, are likely/possible carcinogens, endocrine disruptors, developmental or reproductive toxins, cholinesterase inhibitors, or ground water contaminants (see table 2).

Organic and integrated production

Within Europe there are 0.35 million hectares of organic fruit, berries, citrus, olives and vineyards. One half of this is in Italy and one third in Spain. Smaller but important areas are also found in Portugal, France and Greece. Currently, about 60% of the EU-15 Member States' organic apple sales originate from Italy. The overall market share of organic fruit is only 1 to 2 % in the EU but reaches 4 to 5 % in Switzerland[5].

Integrated production systems favour ecological methods of pest control and aim to reduce pesticide use. However, there is a lack of comparable data on this in different countries because national statistics differ and the distinction between conventional and integrated production is not always clear. However, a survey conducted by the International Organization for Biological and Integrated Control of Noxious Animals and Plants (IOBC) in 1994 showed that integrated pome fruit production and quality assurance schemes were operating in nearly all fruit producing countries in western Europe accounting for approximately 35% of the total area of pome fruit production (approximately 322,000 ha)[6]. This has since increased.

Integrated pest management (IPM) techniques can be economically competitive with conventional methods. In some cases while labour costs are higher under IPM the cost of pest management inputs are up to 50% lower making the total costs equivalent. However, in other circumstances the total costs are higher under IPM. This will in large part depend on a grower's definition and use of IPM, their crop and region, and the cost of local labour.

Some EU countries provide growers with incentives to implement integrated production methods under the Agri-Environmental measures of the Rural Development Programmes. This is likely to have played an important role in encouraging the increase in integrated production. For example, the Belgian government grants a premium per hectare to IPM fruit growers. The total use of pesticides on apples using conventional production methods was one third higher than that for integrated production methods. There was no significant difference in profit between the conventional and integrated systems[7].

Most studies agree that IPM considerably reduces the environmental impacts while yield and income are either equal or lower to conventional. Table 3 shows a measure known as the environmental yardstick (values assigned to sprayings according to their environmental impacts measured in terms of water and soil biodiversity and quality of groundwater resources)[8]. Fungicides and insecticides gave the highest environmental impacts in the environmental yardstick indicator in the conventional systems. In particular, the use of the fungicide thiram (moderate toxicity, developmental or reproductive toxin and suspected endocrine disruptor) and the insecticides propoxur (acute toxicity, carcinogen, cholinesterase inhibitor) and phosalon (moderate toxicity, cholinesterase inhibitor and potential groundwater contaminant) accounted for the bulk of the environmental hazards in the conventional system[9].

A review of the situation in Poland provides insight into the status of IPM within the new Member States. Integrated fruit production was established in Poland in 1991 after the collapse of the communist regime and has expanded since then. In 1999, as

Table 2. Hazards associated with pesticides commonly used on apples

Active Ingredient	WHO (Acute toxicity)	Carcinogenic	EDC/Dev/ Reprotoxin	Ground Water Contaminant	Cholinesterase Inhibitor
Captan	U	Possible	Not Listed	Insuff. Data	Not Listed
Myclobutanil	III	Not Listed	Yes	Insuff. Data	Not Listed
Penconazole	U	Not Listed	Not Listed	Insuff. Data	Not Listed
Carbendazim	U	Possible	Suspected	Insuff. Data	No
Dithianon	III	Not Listed	Not Listed	Insuff. Data	Not Listed
Chlorpyrifos	II	Not Listed	Yes	Insuff. Data	Yes
Methoxyfenozide	U	Not Likely	Not Listed	Potential	No
Thiacloprid	II	Likely	Not Listed	Insuff. Data	Not Listed
Fenoxycarb	U	Likely	Yes	Potential	Not Listed
Triazamate	II	Not Likely	Not Listed	Insuff. Data	No
Glyphosate	U	Not Likely	Not Listed	Insuff. Data	No
Dicamba	III	Not Listed	Yes	Potential	Not Listed
MCPA	III	Possible	Not Listed	Insuff. Data	Not Listed
Mecoprop-P	III	Possible	Not Listed	Potential	No
Diuron	U	Yes	Yes	Yes	Not Listed
2,4-D	II	Possible	Suspected	Potential	No
Glufosinate -ammonium	-	Not Listed	Not Listed	Insufficient Data	No
Paclobutrazol	III	Unclassifiable	Not Listed	Insuff. Data	No

WHO classification – The World Health Organization Recommended Classification of Pesticide by Hazard classifies all pesticides into four groups: Class Ia Extremely Hazardous, Class Ib Highly Hazardous, Class II Moderately Hazardous, Class III Slightly Hazardous, Class U Unlikely

many as 100,000 tonnes of apples from 625 producers (13% of the total production of Polish table apples) were produced using integrated methods. In a survey conducted at the end of 2000, Polish IPM fruit growers stated that they practised IPM mainly due to the reduced applications of pesticides and fertilisers and better contact with advisors. About 90% of the farmers accepted IPM and 93% considered IPM to be the future of fruit production[10].

While in Western Europe increased labour costs are mainly responsible for the higher production costs in organic farming and IPM compared to conventional systems, a study in Poland concluded that organic apple production can be cheaper than conventional production. When organic apple production is higher than 15 tonnes per ha, the variable costs per ha and per kg were almost the same as in conventional orchards. The costs of biological control in organic apple farming were comparable with those of pesticide application. The biggest savings were made in machinery costs, which were about 65% lower in organic orchards. Although labour costs were higher in organic systems they were relatively low compared to Western Europe[11].

Significant pests

A range of pests affect the quality and yield of apples. The most common and damaging insect pests of apple in Europe are codling moth (*Cydia pomonella*), green apple aphid (*Aphis pomi*), rosy apple aphid (*Dysaphis plantaginea*), red spider mite (*Panonychus ulmi*), rust mite (*Aculus schlechtendali*), apple leaf-curling midge (*Dasineura mali*), apple capsid (*Plesiocoris rugicollis*), common green capsid (*Lygocoris pabulinus*), apple leaf miners (*Stigmella* spp, *Lyonetia* spp), woolly aphids (*Eriosoma lanigerum*), owlet moth (*Noctua pronuba*), oriental fruit moth (*Grapholita molesta*), light brown apple moth (*Epipyas posvittana*), apple blossom weevil (*Anthonomus pomorum*) and European apple sawfly (*Haplocampa testudinea*).

Table 3. Average scores on the environmental yardstick for pesticides in Zeewolde in the Netherlands (1992-1999)

	Conventional			Integrated			Minimum		
	Water Life	Soil Life	Ground Water	Water Life	Soil Life	Ground Water	Water Life	Soil Life	Ground Water
Fungicides	4,639	455	1,977	1,727	361	962	1,218	325	862
Insecticides	27,678	504	6,802	3,249	435	4,005	396	191	1
Herbicides	667	116	259	189	32	84	42	8	16
Total	32,463	1,076	9,038	5,165	828	5,052	1,655	524	880

Better pest management

A range of non-chemical techniques are available to reduce pest and disease problems including planting resistant varieties; crop rotation; soil fertility and irrigation management; pest and disease monitoring; cultural practices to avoid introduction of pathogens and eliminate the habitat needed by pests; building and maintaining populations of natural enemies of insect pests (beneficial insects); and measures to block or disrupt pest reproduction.

Beneficial insects

By manipulating habitats, beneficial parasitoids (parasitic wasps which lay their eggs in the larval or egg stage of pest insects) and predators are encouraged in areas bordering orchards[12]. For example, bottle refuges containing corrugated paper and cage refuges containing chopped straw attract earwigs – important predators of aphids and psyllid bugs during the summer. Flowering plants such as cornflower (*Centaurea cyanus*), corn marigold (*Chrysanthemum segetum*) or corn chamomile (*Anthemis arvensis*) attract beneficial insects such as the predatory Anthocoris bugs and hoverflies (Syrphid family). Refuges can be used to manipulate the number of earwigs by either placing them on trees or introducing collected species into an orchard[13]. Beneficials such as hoverflies, cecidomiid flies, lacewings, earwigs and spiders can be attracted into orchards by sowing mixtures of flowering plants alternating with grass strips.

Beneficial insects, such as the mite predators *Typhlodromus pyri*, *Zetzellia mali* and *Anystis baccarum*, have also been successfully artificially introduced into orchards in Europe[14]. *Anystis baccarum* is compatible with several of the most commonly applied fungicides (such as dithianon) in local orchards[15] but not all predatory mites are compatible with fungicides. There are also important predatory bugs from the Miridae, Anthocoridae and Nabidae families.

Several important wasps parasitize the three main species of leaf miners in orchards. If insecticides are avoided these parasitoids can reduce leaf miner population density down to the economic threshold level[16]. A three year experiment in IPM orchards in Hungary saw the number of predatory mites increase after introducing IPM[17].

Broad spectrum insecticides, such as organophosphates, negatively affect non-target organisms, particularly beneficial insects, and can lead to pest resistance and pest outbreaks[18,19]. Pesticides with a narrow spectrum of action, low toxicity, persistence and minimal environmental impacts are more consistent with integrated production. For example, the biopesticide *Bacillus thuringiensis* (Bt) is used successfully to control codling moth. Pesticides such as insect growth regulators like tebufenozide, fenoxycarb and pyripoxyfen; nicotinoid insecticides such as imidacloprid and thiamethoxam; new aphicides such as pymetrozine and pirimicarb; and the miticides pyridaben and abamectin, are quite selective.

Monitoring and control

Traps are effective tools to control and monitor pests, determining the optimum timing for taking action. Pesticide-treated traps are used, for example, to control apple maggot (*Ragolestis pomonella*) and visual traps are effective against tarnished plant bug (*Lygus lineolaris*), European apple sawfly (*Hoplocampa testudinea*) and leafminers (*Pyllonorycter* spp). Apple maggot pheromone traps are a popular method used to monitor and control the populations of tentiform leafminer (*Phyllonorycter mispilella*), codling moth, oriental fruit moth, lesser appleworm (*Grapholita prunivora*), oblique-banded leafroller (*Choristoneura rosaceana*), red-banded leafroller (*Argyrotaenia velutinana*) and European apple sawfly. Pheromone products are also used as mating disruptors, and pheromone-based 'Attract and Kill' feeding stations and traps in combination with natural biopesticides such as azadirachtin (neem) and the concentrated fermentation product spinosad are used to significantly reduce the amount of pesticides applied. Mating disruption based on sex pheromones are effective against key pests such as codling moth (*Cydia pomonella*), oriental fruit moth (*Grapholita molesta*), and light brown apple moth (*Epipyas posvittana*). Regular examination of trees and fruit, up to three times a week depending on the season, along with a good weather forecasting and warning system is a key aspect of IPM.

Zero pesticide residues

An IPM system has been developed in the UK to produce pesticide-free apples. Conventional pesticides, such as diflubenzuron, thiaclopyrid or fenoxycarb (but excluding organophosphate insecticides), are used up to petal fall and after harvest while biocontrol methods such as granulosis virus and *Bacillus thuringiensis*, sulphur and cultural methods are used between petal fall and harvest. Pest control, although satisfactory, has been more expensive due to the higher costs of selective insecticides[20]. The reduction of insecticide spraying[21], particularly of broad spectrum insecticides[22], has been key in reducing or eliminating pesticide residues in commercial apple orchards.

Diseases

The most important diseases with economic importance for apples are scab (*Venturia inaequalis*), powdery mildew (*Podoshaera leucotrycha*), fruit canker, storage moulds such as nectria, fusarium, gloeosporium and botrytis, and fireblight.

Controlling disease in conventional apples requires many preventive fungicide treatments. In IPM, apart from selecting the least toxic fungicides, applications are timed according to the risk of infection. Weather stations identify optimum conditions for fungal infection. Use of disease-resistant or tolerant apple varieties can further reduce the need for pesticides[23]. A group of Belgian and French farmers is reintroducing old apple varieties[24].

Pesticide reduction information

The latest coordinated EU residue monitoring results show over 60% of apple samples had detectable residues, while 2% had residues above the legal limit. The most frequently detected were pesticides from the benomyl group (20%), chlorpyrifos (16%) and diphenylamine (15%)[25].

The reliance on synthetic pesticides can be reduced or even eliminated with careful management which involves growing disease-resistant cultivars and opting for least-toxic alternatives such as biological and cultural controls. Residues on fruits at harvest can be reduced by maximizing the withholding period after application until harvesting and by minimizing post-harvest chemical treatments. No pesticide should normally be applied within 21 days of harvest. However, in seasons where there is significant rainfall and/or a high risk of pests or diseases during late summer, insecticide or fungicide sprays may exceptionally be applied nearer to harvest if required, but not if post-harvest fungicide treatment is to be applied[26].

There is an IOBC list of pesticides and chemicals approved for use in integrated production systems. However, these ought only to be applied in cases where non-chemical measures are insufficient.

The pesticides approved for integrated fruit production differ from country to country. The UK has guidelines for best practice in Integrated Pest and Diseases Management in apple production, including a list of approved pesticides and a check list for integrated pest and disease management tasks[27]. IOBC guidelines for integrated apple production focus on preventative, indirect measures to keep pests under economical thresholds (table 4). National or regional producer organisations can apply for endorsement by the IOBC to verify their compliance with these guidelines. In addition, the IOBC emphasizes that farm managers must be professionally trained in all aspects of integrated production by attending locally organized training courses.

Marketing

Apples sold in the European market should conform to set sizes and a set of cosmetic standards specifying shape, colour and absence of pests, diseases or damage. If the fruit is damaged or overripe, farmers can sell the fruit in the juice market providing there are no worms or rot. However, the juice price is usually about a quarter of the fresh apple price, and does not cover production costs.

Besides expecting cosmetically perfect apples, consumers are increasingly concerned with the presence of pesticide residues. A recent Eurobarometer survey shows that 63% are concerned about pesticide residues in fruit and vegetables[28]. This is the main driver for the development of pesticide-free fruit. In the UK, for example, supermarket chains are adopting production and marketing strategies to differentiate their products on the basis of reductions in pesticide residues[29]. In Italy, a not-for-profit environmental organisation created a self-certification scheme for products sold without pesticide residues, including apples. Production is based on IPM techniques[30].

Conclusions

Despite the growth of integrated and organic apple production in Europe most apples are still produced using conventional methods. Pesticides with serious health and environmental hazards are used and, in addition, the number of sprays per season is high. This results in high input costs, health risks and the presence of pesticide residues often exceeding the Maximum Residue Limits.

But current IPM practices are not the whole solution. Highly hazardous pesticides such as chlorpyrifos are currently permitted under some IPM apple production systems in Europe. This practice must change if IPM is to be considered (and marketed) as better for the environment and human health. In addition, the level of implementation of IPM guidelines varies in Europe, because there is not one single definition.

We need pesticide use reduction targets to change conventional orchard production and encourage the growth of organic orchards. Given the diversity of IPM guidelines in Europe, a set of minimum criteria should be laid out in general and per crop. These criteria should include pesticide use reduction targets and prohibit certain pesticides based on their intrinsic hazards. According to the new Framework Directive to achieve a Sustainable Use of Pesticides COM (2006) 373, proposed by the European Commission in 2006, general IPM standards should be adopted by all farmers from January 2014 onwards while crop specific standards shall be adopted on a voluntary basis[31]. This would be a major set-back to pesticide reduction goals because in this process the necessary level of crop-specific detail would be lost. Pesticide Action Network Europe is calling for crop-specific standards established at the national/regional level and applied on a compulsory basis.

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Table 4. IOBC guidelines for pome fruit production

Function	Preferred options	Strict rule/prohibition
Conserving the orchard environment	At least 5% of farm surface must be managed as ecological compensation areas (no fertilizer and pesticide input) to maintain biodiversity.	
Site, rootstocks, cultivar and planting system for new orchards	Cultivars resistant to diseases or pests are preferred. Plant material should be virus-free. Single rows are preferred.	Chemical soil sterilization is not permitted.
Soil management and tree nutrition	The total maximum nitrogen input, period and methods of application should be set to minimize leaching and after measured by soil analysis.	
Alleyways and weed-free strip	Non competitive herb/grass mixtures are recommended.	Bare soil management is not permitted.
Irrigation	Daily rainfall must be measured and soil moisture deficit estimated.	
Tree training and management	Excessive growth should be controlled by cultural measures. Pruning should aim to achieve a healthy and manageable size of trees.	
Fruit management	Hand thinning is preferred.	
Integrated plant protection	Priority must be given to natural, cultural, biological, genetic and biotechnical methods. Pesticides only be used when justified and the most selective, least toxic and persistent used. Populations of pests, diseases and weeds must be monitored and recorded. Populations of key natural enemies must be preserved and phytoseiid predators introduced where not present.	Benzimidazole and dithiocarbamate fungicides, sulphur and residual herbicides permitted with restrictions. Pyrethroids, non-naturally occurring plant growth regulators, organo-chlorines and toxic, water polluting orvery persistent herbicides not permitted. No pesticide to be applied within 21 days of harvest.
Application methods	Sprayers must be regularly serviced and calibrated and must comply with spray testing requirements. Statutory buffer zones must be observed.	Radial flow air assisted sprayers should be avoided and progressively replaced.
Harvesting and storage	Fruit in store should be regularly monitored and only fruit of sound quality can be certified.	
Post-harvest treatments	Fungicide treatments are only permitted where non-chemical methods are not available and cultivars are susceptible.	Use of synthetic, non-natu rally occurring anti-oxidants for control of scald and other disorders are not permitted.

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