The Bitter Taste of Europe's Apple Production

and how Ecological Solutions can Bloom

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GREENPEACE

Introduction: The Bitter Taste of Europe's Apple Production and how Ecological Solutions can Bloom

Apple and fruit production is one of the most chemical intensive sectors in Europe's agriculture. Considering that the EU-27 is one of the world's leading producers and consumers of apples, and that apples are EU-27's most popular fruit[1], the importance of this sector becomes clear. Producing our food within an agricultural system highly dependent on synthetic-chemical pesticides doesn't come without consequences. The impacts of industrial agriculture are widespread, ranging from contaminated soil and water, to impacts on bees and other beneficial insects, as well as on farmers, their families and consumers. The growing concern about Europe's massive pesticide use goes hand in hand with an increasing need to search for ecological solutions.

This report exposes on one hand the toxic burden that industrial apple production in Europe is creating, and on the other hand it showcases a selection of existing solutions already applied by ecological farmers all over Europe to protect their crops without using synthetic-chemical pesticides.

The first part "An analysis of Pesticides in European Apple Orchards", contains comprehensive testing results of soil and water samples taken from fields in apple orchards in 12 European countries. Across the entire set of 85 samples taken, a total of 53 different pesticides were found, with 75% of all samples (soil: 78%, water: 72%) containing residues of at least one of these pesticides. 70% of the pesticides identified have very high overall toxicity to human and wildlife. The testing results prove that several chemicals are used to produce apples in Europe and that they remain in the ground polluting the ecosystem after application. The samples represent a "snapshot" of the situation at the beginning of blossom onset. The results show that a complex array of pesticides can be detected in soils and waters associated with apple orchards in Europe.

The pesticides most frequently found in soil were the fungicide boscalid (38% of samples) with concentrations up to 3.6 mg/kg, DDT (26% of samples) with up to 0.4 mg/kg, and chlorpyrifos-ethyl with up to 0.26 mg/kg. The most abundant pesticides in water were also boscalid (40%, up to 23 µg/l) and chlorantraniliprole (40%, up to 2 µg/l). All 4 pesticides have a very high overall toxicity.

The highest number of pesticides in soil were detected in Italy (18 pesticides from 3 samples), followed by Belgium (15 pesticides from 3 samples) and France (13 pesticides from 6 samples). In the water sampling the highest counts were detected in Poland (13 pesticides from 3 samples), followed by Slovakia (12 pesticides from 3 samples) and Italy (10 pesticides from 2 samples). From the 38 pesticides found in the water samples, 8 have a very high toxicity against water organisms. One pesticide found in the soil samples have very high earthworm toxicity; eight of the pesticides found in all samples have very high bee toxicity. Twenty of the pesticides found are very persistent, while 5 found in the soil samples have a high leaching potential. These environmentally critical properties enhance the threat from toxic pesticides.

Seven of the pesticides found are currently not approved for use in the EU and can only be used with exceptional member state authorisations. These residues may be present as a result of historical use of these pesticides, although in the case of carbendazim could result from degradation of other active ingredients.

Five samples exceed the average Environmental Quality Standards for High Priority Water Contaminants of the EU Water Framework Directive, and two of them even exceed the maximum standard (chlorpyrifos-ethyl from Italy).

Given the cocktails of pesticides detected in the water and soil of apple orchards all over Europe the scale of the problem becomes quite clear. The reliance on synthetic-chemical pesticides in European apple production needs to be addressed urgently and seriously, and ecological pest management and alternatives to these chemicals need to be scaled up and implemented immediately.

The second part of this report "Ecological Pest Management and Alternative Control For The Most Important Diseases And Pests in Apples" showcases a number of ecological solutions in apple growing and their practical implementation. The report analyses different approaches to reduce the need for the use of chemical pesticides. A balanced agro-ecosystem is the key factor for ecological apple production to increase resilience to pests and diseases, and to nurture and protect beneficial organisms. Fertilisation, soil management, cover crops and pruning practices improve growth and the nutritious status of the apple trees, as well as directly and indirectly decreasing the susceptibility of the tree and the fruits to disease. A stable Agro-Ecosystem benefits natural enemies, e.g. predatory wasps, by improving the availability of pollen and nectar. Conserving natural enemies is key for the management of pests such as the European Red Mite.

Monitoring deserves close attention as well, as pathogens depend on environment and especially on weather conditions. For a timely response to diseases, temperature, moisture and other weather forecasts need to be taken into consideration. Smart breeding techniques producing cultivars resistant to specific diseases such as apple scab, when applied in a balanced ecosystem, serve producers with a healthier and more resilient crop and therefore reduce the need for chemical interventions. Other relevant topics discussed in this chapter are natural predators to keep pests under control, companion planting to benefit soil health, attracting beneficial insects and repelling pests. Agroforestry, together with a mixture of crops, has also been proven to reduce pest infestation in apple growing.

Besides detailing the preventive approach, the report also presents ecological management tools to employ when specific pests and diseases occur, such as using pheromone disruptors to control the codling moth. Another example is the granulosis virus which is successfully applied by organic farmers against e.g. caterpillars. Horsetail extract on the other hand can stimulate the natural defences of apple trees. The last chapter provides the insights of an organic apple grower with 30 years of experience and showcases the practical feasibility of the methods detailed earlier in the report. Ecological apple growing offers modern solutions to producing healthy, tasty fruits, without contaminating our soils and water.

The problems of contaminated soil and water in European apple production which this report exposes, and the broad variety of existing and promising solutions provided by ecological farming methods, underline the urgent need to upscale ecological farming.

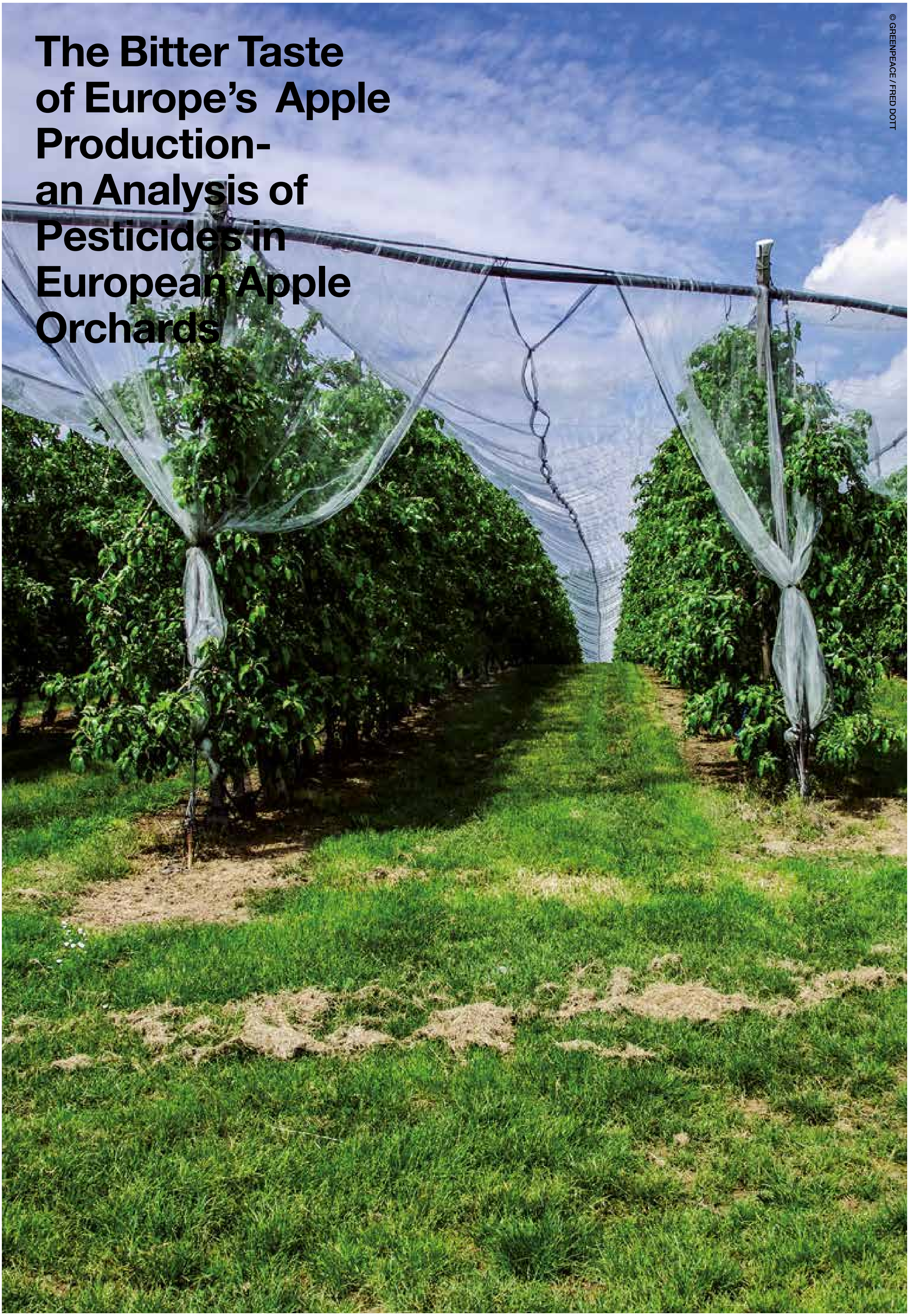
Greenpeace therefore urges EU Member States, as a first step, to:

- **phase out of the use of synthetic-chemical pesticides in agriculture.** Priority should be given to banning pesticides which have carcinogenic properties, are mutagenic or toxic to reproduction, and interfere with the hormone system (EDCs) as well as pesticides with neurotoxic properties;
- **support and scale up further research and development of non-chemical alternatives to pest management, focusing specifically on ecological farming practices.**

Ecological farming combines an understanding of nature and new scientific findings, carried out by ecological farmers every day. It is a food and agriculture system based on the principles of agro-ecology, protecting biodiversity, ensuring soil health and clean water, implementing ecological pest control, and enhancing the resilience of the food system. It gives people not corporations control of the food chain and benefits farmers and rural communities.

1. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Fresh%20Deciduous%20Fruit%20Annual_Vienna_EU-27_10-28-2011.pdf

The Bitter Taste of Europe's Apple Production- an Analysis of Pesticides in European Apple Orchards



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01

Summary

Executive summary

A total of 49 soil samples were collected from conventionally managed apple orchards in 12 European countries during April 2015, along with 36 water samples collected either within or adjacent to apple orchards, and analyzed for pesticide residues. Across the entire set of the 85 samples taken, a total of 53 different pesticides were found, with 78% of the soil samples and 72% of the water samples containing residues of at least one of these pesticides. 70% of the pesticides identified are ranked in the Greenpeace Germany Blacklist as having very high overall toxicity either to humans, to wildlife or to both.

The samples represent a "snapshot" of the situation at the start of blossoming. The results show that a complex array of pesticides can be detected in soils and waters associated with apple orchards in Europe. Although the precise origin of these pesticides cannot be determined, their direct use (either historic or recent) in the orchards in which the samples were collected seems the most likely explanation for most of the active ingredients identified, with some possibly arising as partial break-down products of other pesticides. In turn, these contaminants can then enter the wider environment.

The number of pesticides detected in the soil samples ranged from 0 (11 samples) to 13 (2 samples) and in the water samples from 0 (10 samples) to 12 (1 sample). More than half of the soil and water samples combined (56%) had at least 2 pesticides and in 5 samples, 10 or more pesticides were found.

The most frequently found pesticides in soil were the fungicide boscalid (38 % of samples) with concentrations up to 3.6 mg/kg, DDT, as DDE and DDD (26 % of samples) at up to 0.4 mg/kg and chlorpyrifos-ethyl (20% of samples) at up to 0.26 mg/kg. The most frequently detected pesticides in the water samples were boscalid (40%, up to 23 µg/l) and chlorantraniliprole (40%, up to 2 µg/l). All 4 of these pesticides have a very high overall toxicity scores.

Considered by country, the highest numbers of pesticides in soil were detected in the samples from Italy (18 pesticides in total, across 3 samples), followed by Belgium (15 pesticides in total, across 3 samples) and France (13 pesticides in total, across 6 samples). In the water samples, the highest counts were detected in Poland (13 pesticides in total, across 3 samples), followed by Slovakia (12 pesticides in total, across 3 samples) and Italy (10 pesticides in total, across 2 samples).

Of the 38 pesticides found in the water samples, 8 are known have a very high toxicity towards aquatic organisms. One pesticide found in the soil samples has very high toxicity to earthworms; eight of the pesticides found in either soil or water samples are regarded as highly toxic to bees.

20 of the pesticides found are considered to be very persistent and five of those found in the soil samples have a high leaching potential; these environmentally critical properties can increase the threat posed by these toxic pesticides.

Seven of the pesticides found are currently not approved for use in the EU and can only be used with exceptional member state authorizations. These residues may be present as a result of historical use of these pesticides, although in the case of carbendazim they could result from degradation of other active ingredients such as thiophanate-methyl, which is approved for use in the EU

The concentrations of certain pesticides present in five samples were found to exceed the prescribed average Environmental Quality Standards for High Priority Water Contaminants under the EU Water Framework Directive, while in two of them, both from Italy, the maximum prescribed standard for chlorpyrifos-ethyl was exceeded.

For at least 5 of the pesticides found, combination effects with other pesticides have been reported in the scientific literature, although these specific combinations were not found together in this study.

Recommendations

1. Policy should be formulated with a view to reducing, and ultimately, phasing out the use of synthetic chemical pesticides by adoption and use of ecological farming systems.

2. As part of the investigation and auditing process, particular attention should be given to active ingredients which appear to be in use but which are not authorized, with a view to possible legal action.

3. There is a need to implement a systematic EU wide program of surveillance monitoring in order to establish a body of baseline data which can be used to assess spatial patterns of environmental contamination and whether particular agricultural activities are associated with "hotspots" of contamination with pesticides.

4. Research efforts aimed at better understanding the environmental fate and toxicological effects of mixtures of pesticides should be intensified.

5. There is an urgent need for member state authorities to investigate, record, report and audit which active ingredients are in use in their jurisdictions and in which agricultural sectors these are being used.

© GREENPEACE • PESTICIDE USE IN APPLE PLANTATION IN GERMANY

© GREENPEACE / FRED DOTT - GREENPEACE CAMPAIGNER IS TAKING GROUND AND WATER SAMPLES IN AN APPLE PLANTATION.

02

Materials & Methods

Sampling

Apple Orchard Soil and Surface waters

Soils from apple orchards (Table 1) , along with surface waters either from within or adjacent to apple orchards (Table 2), were sampled in 12 countries (Austria, Belgium, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Slovakia, Spain, Switzerland) during April 2015, either just before blossoming or during the early stages of flowering. These samples, accordingly, allow the determination of a snapshot of agricultural substances present in media other than harvested products at a specific point in the cultivation and production cycle of apples. Soil samples (n=49) were taken using stainless steel trowels, cleaned between sites to avoid cross-contamination, and were a composite of samples (0-5 cm) taken diagonally through each orchard (rather than at the edge). These composite samples were placed in a 500 ml bottle supplied by the analysing laboratory. Water samples (n=36) were taken from streams, ditches, canals or puddles either in the orchards or directly adjoining them, using a clean 1 l glass bottle supplied by the analysing laboratory. Samples were immediately sent for analysis and were processed by the receiving laboratory within 2 weeks of receipt.

Table 1: Details of soil samples from apple orchards including country and area

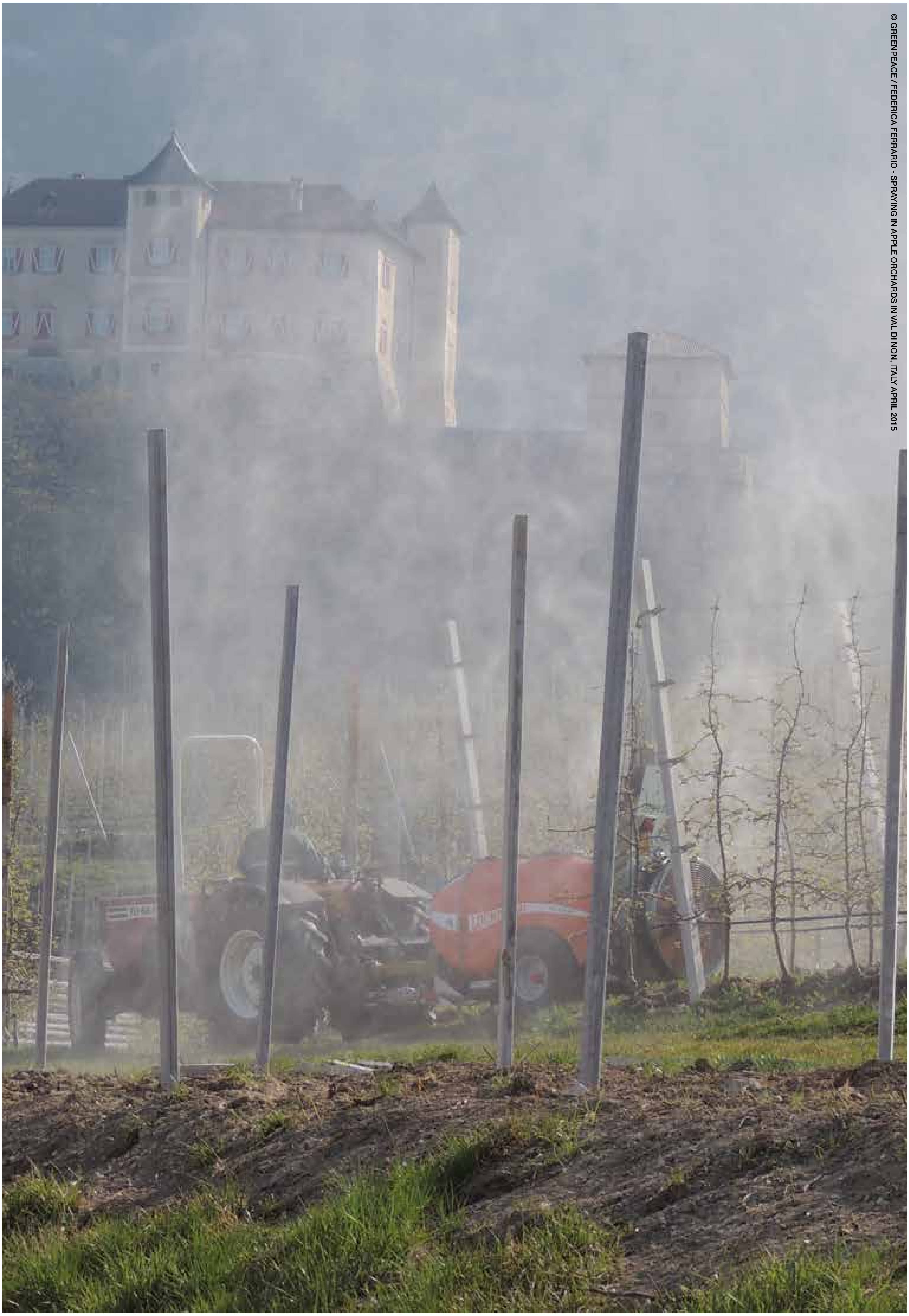
Country	No. of soil samples	Area
Austria	3	2 x Puch bei Weiz, 1 x Itztal
Belgium	3	3 x Haspengouw
France	6	2 x Limousin, 2 x Provence-Alpes-Côte d'Azur, 2 x Midi-Pyrénées
Germany	5	5 x Altes Land
Greece	3	1 x Korinthia, 1 x Imathia, 1 x Arkadia
Hungary	6	6 x Kiskunság
Italy	3	2 x Val di Non, 1 x Valtellina
Netherlands	5	1 x Velddriel, 1 x Waardenburg, 1 x Middelweert, 1 x Luttelgeest, 1 x Marknesse
Poland	3	1 x Wierzchucice, Kujawsko-pomorskie voivodeship, 1 x Świniokierz Dworski, Łódzkie voivodship, 1 x Wólka Łęczeszycka, Mazowieckie voivodship
Slovakia	3	2 x Nitriansky kraj, 1 x Trnavský kraj
Spain	2	2 xCataluña
Switzerland	7	7 x Lake of Bodensee region (Katon Thurgau)
Total soil sample from apple orchards	**49**	

Table 2: Details of water samples from apple orchards including country, area and type of water collected.

Country	No. of water samples	Type of water body	Area
Austria	1	Puddle	1 x Itztal
Austria	1	stream between orchard fields	1 x Puch bei Weiz
Austria	1	pipe draining orchard field	1 x Itztal
Belgium	1	stream draining apple orchard	1 x Haspengouw
France	2	lake water	2 x Limousin
France	3	surface water	2 x Provence-Alpes-Côte d'Azur, 1 x Midi-Pyré-nées
Germany	5	closed ditch	5 x Altes Land
Greece	1	stream running through orchard	1 x Korinthia
Greece	1	Puddle	1 x Imathia
Italy	2	Canal	1 x Val di Non, 1 x Valtellina
Netherlands	3	ditch within orchard field	1 x Velddriel, 1 x Middelweert, 1 x Luttelgeest
Netherlands	2	ditch between orchard fields	1 x Marknesse, 1 x Waardenburg
Poland	3	Water	1 x Wierzchucice, Kujawsko-pomorskie voivode-ship, 1 x Świniokierz Dworski, Łódzkie voivodship, 1 x Wólka Łęczeszycka, Mazowieckie voivodship
Slovakia	3	puddle water	2 x Nitriansky kraj, 1 x Trnavský kraj
Spain	1	puddle water	1 x Cataluña
Switzerland	1	surface runoff water	1 x Lake of Bodensee region (Katon Thurgau)
Switzerland	5	drainage pipe runoff water	5 x Lake of Bodensee region (Katon Thurgau)
Total no. of water samples from apple orchards	**36**		

Analysis and Treatment of Results

All samples were analysed at a laboratory in Europe using accredited (ISO/IEC 17025:2005) multi-residue analysis methods targetting a wide range of pesticides and their metabolites (600 parameters in soils and 600 parameters in waters). Details of extraction methods (where appropriate) and analytical methodologies are given in Annex A. Where pesticides were reported as the applied pesticide with no metabolites, no summation was necessary. Where pesticides were present as the applied substance and/or as metabolites, they were summed as outlined in Annex B.

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03

Results

Pesticides in soil samples from apple orchards

A total of 37 different pesticides were detected in total across the set of 49 soil samples. The number of pesticides detected in soil samples (Fig. 1) ranged from 0 (11 samples) to 13 (2 samples). Pesticides detected in soil samples are tabulated by both country (Table 3) and substance (Table 4). Herbicides, fungicides and insecticides were detected in samples, with some substances (e.g. tebuconazole and terbuthylazine) having multiple uses (Table 4). The most frequently detected pesticide was the fungicide boscalid, which was present in 19 samples (38 % of samples) with concentrations ranging from 0.11 mg/kg to 3.6 mg/kg. Other frequently detected pesticides (detected in >20 % of samples) were DDT (as DDE and DDD), detected in 13 samples (26 % of samples), at a concentration range of 0.015-0.4 mg/kg and chlorpyrifos-ethyl, found in 10 samples, (20 % of samples), at a concentration range of 0.026-2.6 mg/kg. By country (Table 3), the highest numbers of pesticides were detected in samples from Italy (18 pesticides in total, across 3 samples), followed by Belgium (15 pesticides in total, across 3 samples) and France (13 pesticides in total, across 6 samples).

Table 3: Pesticides detected in soil samples from apple orchards by country. Sampling period, number of samples and concentration ranges for each pesticide are given.

Country	Sampling period	Number of soil samples	Pesticides detected, (number of samples in which found) [concentration range in mg/kg]
Austria	30-31 March 2015	3	Boscalid (1) [0.14] Chloropyrifos-ethyl (1) [0.077], Endosulfan (as Endosulfan sulphate) (1) [0.076], Endrin (1) [0.04], Fluquinconazole (1) [0.11], Pendimethalin (1) [0.25]
Belgium	11-12 April 2015	3	Boscalid (3) [1.4-3.6], Carbendazim (1) [0.11], Chlorantraniliprole (3) [0.083-0.14], Cyprodinil (1) [0.11], Difenoconazole (2) [0.2-0.26], Diflufenican (2) [0.36-0.53], Indoxacarb (2) [0.18-0.061], Linuron (1) [0.06], Myclobutanil (2) [0.018-0.1], Penconazole (2) [0.082-0.12], Pendimethalin (1) [0.13], Pirimicarb (1) [0.076], Pyraclostrobin (2) [0.1-0.16], Thiabendazole (1) [0.12], Triadimenol (1) [0.21]
France	9 April 2015	6	Boscalid (4) [0.28-0.72], Chlorantraniliprole (2) [0.05-0.057], Chlorpyrifos-ethyl (4) [0.02-0.26], Cyprodinil(1) [0.23], DDT (2) [0.015-0.023], Difenoconazole (2) [0.073-0.096], Fenbuconazol (1) [0.061], Fludioxonil (4) [0.069-0.33], Oxadiazon (1) [0.041], Oxyfluorfen (2) [0.035-0.1], Pendimethalin (1) [0.16], tau-Fluvalinate (3) [0.018-0.047], Tetraconazole (1) [0.087]
Germany	15 April 2015	5	Carbendazim (2) [0.072-0.13], Chlorantraniliprole (2) [0.1-0.16], Cyprodinil (2) [0.077-0.099], DDT (2) [0.083-0.184], Fludioxonil (1) [0.07], Fluquinconazole (1) [0.03], Methoxyfenozide (1) [0.062-0.091], Penconazole (2) [0.05-0.11], Pirimicarb (1) [0.052], Tebuconazole (2) [0.075-0.077]
Greece	3-6 April 2015	3	Boscalid (1) [0.073], Chlorantraniliprole (1) [0.089], Dieldrin (1) [0.072]

Hungary	15 April 2015	6	DDT (3) [0.015-0.11], Tebuconazole (5) [0.056-0.079], Tetraconazole (1) [0.064]
Italy	10-11 April 2015	3	Boscalid (2) [0.16-0.31], Carbendazim (1) [0.57], Chlorantraniliprole (1) [0.062], Chlorpyrifos-ethyl (1) [2.1], Deltamethrin (1) [0.07], Difenoconazole (1) [0.23], Endosulfan (as Endosulfan sulphate) (1) [0.03], Etofenprox (1) [0.29], Fenhexamid (1) [0.18], Fludioxonil (1) [0.069], Imidacloprid (1) [0.081), Indoxacarb (1) [0.32], Iprodione (1) [1.8], Oxyfluorfen (2) [0.055-0.21], Penconazole (1) [0.15], Pirimicarb (1) [0.15], Pyraclostrobin (1) [0.19], Tebuconazole (1) [2.2]
Netherlands	14 April 2015	5	Boscalid (3) [0.12-0.25], DDT (4) [0.036-0.4],
Poland	8 April 2015	3	Boscalid (3) [0.11-0.31], DDT (2) [0.019-0.092], Difenoconazole (1) [0.095], Flusilazol (2) [0.05-0.23], Methoxyfenozide (1) [0.18]
Slovakia	9 April 2015	3	Boscalid (2) [0.11-0.35], Indoxacarb (1) [0.02]
Spain	26-27 March 2015	2	No pesticides detected
Switzerland	2-14 April 2015	7	2,4-D (1) [0.084], Chlorpyrifos--ethyl (4) [0.03-0.21], Difenoconazole (2) [0.083-0.14], Endosulfan (as Endosulfan sulphate) (1) [0.03], Mecoprop (MCPP) (1) [0.098], Myclobutanil (1) [0.023], Penconazole (2) [0.053-0.1]

Table 4: Frequency of detected pesticides in soil samples from apple orchards. Pesticides are ordered alphabetically with the type of pesticide, number and percentage of samples in which they were found, together with the country of origin and overall concentration or concentration range.

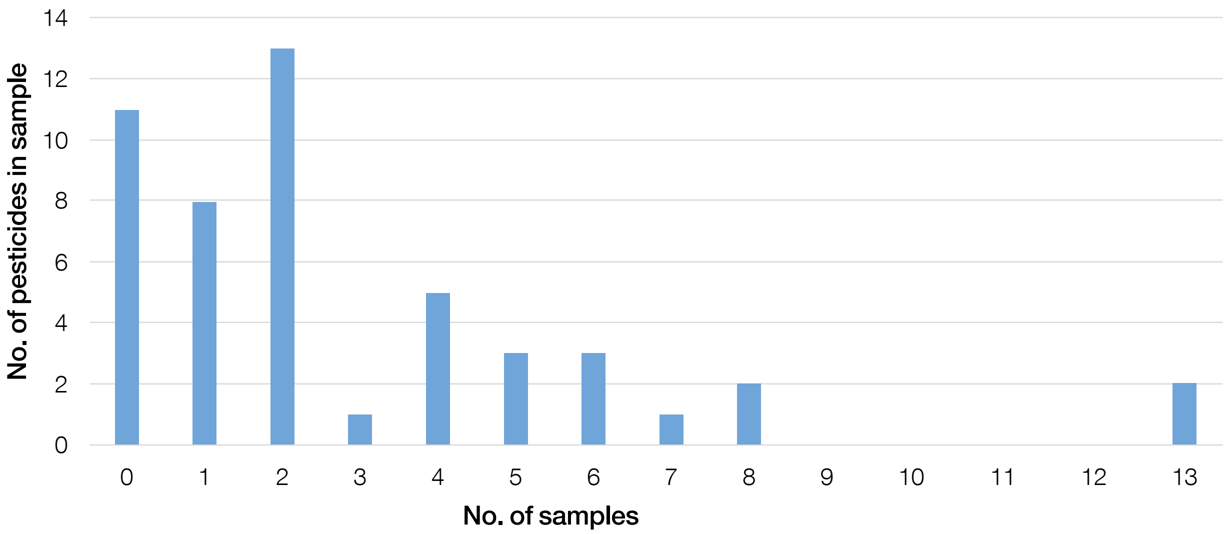
Pesticide	Class/ type	Frequency of detection in soil samples		Countries in which detected (number of samples) [concentration range in mg/kg]
		No. of samples	% samples	
2,4-D	H	1	2	Switzerland (1) [0.084]
Boscalid	F	19	38	Austria (1) [0.14], Belgium (3) [1.4-3.6], France (4) [0.28-0.72], Greece (1) [0.073], Italy (2) [0.16-3.1], Netherlands (3) [0.12-0.25], Poland (3) [0.11-0.31], Slovakia (2) [0.11-0.35].
Carbendazim	F	4	8	Belgium (1) [0.11], Germany (2) [0.072-0.13], Italy (1) [0.57]
Chlorantraniliprole	I	9	18	Belgium (3) [0.083-0.14], France (2) [0.05-0.057], Germany (2) [0.1-0.16], Greece (1) [0.089], Italy (1) [0.062]
Chlorpyrifos-ethyl	I (op)	10	20	Austria (1) [0.077], France (4) [0.02-0.26], Italy (1) [2.1], Switzerland (4) [0.03-0.21]
Cyprodinil	F	4	8	Belgium (1) [0.11], France (1) [0.23], Germany (2) [0.077-0.099]
DDT (as DDD and DDE)	I	13	26	France (2) [0.015-0.023], Germany (2) [0.083-0.184], Hungary (3) [0.015-0.11], Netherlands (4) [0.036-0.4], Poland (2) [0.019-0.092]
Deltamethrin	I	1	2	Italy (1) [0.07]
Dieldrin	I	1	2	Greece (1) [0.072]
Difenoconazole	I	8	16	Belgium (2) [0.2-0.26], France (2) [0.073-0.096], Italy (1) [0.23], Poland (1) [0.095], Switzerland (2) [0.083-0.14]
Diflufenican	H	2	4	Belgium (2) [0.36-0.53]
Endosulfan (as Endosulfan sulphate)	I	3	6	Austria (1) [0.076], Italy (1) [0.03], Switzerland (1) [0.03]
Endrin	I	1	2	Austria (1) [0.04]
Etofenprox	I	1	2	Italy (1) [0.29]
Fenbuconazol	F	1	2	France (1) [0.061]
Fenhexamid	F	1	2	Italy (1) [0.18]
Fludioxonil	F	6	12	France (4) [0.069-0.33], Germany (1) [0.07], Italy (1) [0.069]
Fluquinconazole	F	2	4	Austria (1) [0.11], Germany (1) [0.03]
Flusilazol	F	2	4	Poland (2) [0.05-0.23]
Imidacloprid	I (neo)	1	2	Italy (1) [0.081]
Indoxacarb	I	4	8	Belgium (2) [0.018-0.061], Italy (1) [0.32], Slovakia (1) [0.02]
Iprodione	F	1	2	Italy (1) [1.8]
Linuron	H	1	2	Belgium (1) [0.06]
Methoxyfenozide	I	3	6	Germany (2) [0.062-0.091], Poland (1) [0.18]
Mecoprop (MCPP)	H	1	2	Switzerland (1) [0.098]
Myclobutanil	F	3	6	Belgium (2) [0.018-0.1], Switzerland (1) [0.023]
Oxadiazon	H	1	2	France (1) [0.041]
Oxyfluorfen	H	4	8	France (2) [0.035-0.1], Italy (2) [0.055-0.21]

Penconazole	F	7	14	Belgium (2) [0.082-0.12], Germany (2) [0.05-0.11], Italy (1) [0.15], Switzerland (2) [0.053-0.1]
Pendimethalin	H	3	6	Austria (1) [0.25], Belgium (1) [0.13], France (1) [0.16]
Pirimicarb	I	3	6	Belgium (1) [0.076], Germany (1) [0.052], Italy (1) [0.15]
Pyraclostrobin	F	3	6	Belgium (2) [0.1-0.16], Italy (1) [0.19]
tau-Fluvalinate	I, Ar	3	6	France (3) [0.018-0.047]
Tebuconazole	F, P	8	16	Germany (2) [0.075-0.077], Hungary (5) [0.056-0.079], Italy (1) [2.2]
Tetraconazole	F	2	4	France (1) [0.087], Hungary (1) [0.064]
Thiabendazole	F	1	2	Belgium (1) [0.12]
Triadimenol	F	1	2	Belgium (1) [0.21]

Key

Al = algicide, Ar = acaricide, F = fungicide, H = herbicide, I = insecticide, M = microbiocide, P = plant growth regulator, op = organophosphate, neo = neonicintinoid

Fig. 1 Frequency of pesticides detections in soil samples from apple orchards



Pesticides in water samples collected from or adjacent to apple orchards

A total of 38 different pesticides was detected across the set of 36 water samples. The number of pesticides detected in individual samples (Fig. 2) ranged from 0 (10 samples) to 12 (1 sample). Pesticides detected in water samples are tabulated by both country (Table 5) and substance (Table 6). Examples of herbicides, fungicides and insecticides were detected in the samples, with some substances having multiple uses (Table 6). Diethyltoluamid (DEET) was found in 2 samples (Belgium (1 sample, 0.1 µg/l), Netherlands (1 sample, 0.067 µg/l)) but is omitted from the tables as the presence of this insect repellent could have arisen as a result of chance contamination from the use of this as a repellent by the persons taking the samples. The two most frequently detected pesticides (detected in > 20 % of samples) were boscalid, present in 14 samples (40 % of samples) with concentrations ranging from 0.069 µg/l to 23 µg/l and chlorantraniliprole, also present in 14 samples (40 % of samples) with concentrations ranging from 0.067 µg/l to 2.0 µg/l. By country (Table 5), the highest number of pesticides was detected in samples from Poland (13 pesticides in total, across 3 samples), followed by Slovakia (12 pesticides in total, across 3 samples) and Italy (10 pesticides in total, across 2 samples).

Table 5: Pesticides detected in water samples collected from, or adjacent to, apple orchards by country. Sampling period, number of samples and concentration ranges for each pesticide are given.

Country	Sampling period	Number of water samples	Pesticides detected, (number of samples in which found) [concentration range in µg/l]
Austria	26-30 March 2015	3	Boscalid (1) [0.069], Chlorpyrifos-ethyl (1) [0.15], Chlorpyrifos-methyl (1) [19], MCPA (1) [0.082], Pendimethalin (1) [0.19]
Belgium	9 April 2015	1	Boscalid (1) [1.6], Chloridazon (1) [0.9], Cyprodinil (1) [0.058], Diflufenican (1) [0.091], Dimethomorph (1) [0.2], Isoproturon (1) [0.95], Linuron (1) [1.6]
France	11-12 April 2015	5	2,4-D (2) [0.62-7.8], Acetamiprid (3) [1.4-12], Boscalid (3) [0.16-15], Chlorantraniliprole (3) [0.084-1.5], Fludioxonil (2) [0.17-2], Metalaxyl (1) [0.066], Penconazole (1) [0.15], Propyzamide (1) [0.1], Tetraconazole (2) [0.12-0.24]
Germany	15 April 2015	5	Chlorantraniliprole (4) [0.07-0.63], Imidacloprid (1) [0.067]
Greece	3-6 April 2015	2	Boscalid (1) [3.3], Chlorantraniliprole (1) [1.1], Myclobutanil (1) [0.16], Tebuconazole (1) [0.39]
Italy	10-11 April 2015	2	Boscalid (1) [0.31], Bupirimat (1) [0.59], Buprofezin (1) [0.39], Carbendazim (1) [0.19], Chlorpyrifos-ethyl (2) [0.16- >50], Methoxyfenozide (1) [0.29], Oxadiazon (1) [>50], Penconazole (1) [1.3], Pyrimethanil (1) [1.1], Thiophanate-methyl (1) [0.065]
Netherlands	14 April 2015	5	Boscalid (2) [0.08-0.084], Carbendazim (1) [0.05], Chlorantraniliprole (1) [0.075], Methoxyfenozide (1) [0.16], Mecoprop (MCPP) (2) [0.11-0.23]
Poland	7-8 April 2015	3	Acetamiprid (1) [0.07], Boscalid (2) [3.5-23], Carbendazim (2) [0.14-0.34], Chlorantraniliprole (2) [0.067-0.5], Chlorpyrifos--ethyl (1) [0.1], Cyprodinil (1) [0.24], Fludioxonil (1) [0.49], Indoxacarb (1) [0.37], Methoxyfenozide (1) [1.5], Pyraclostrobin (1) [0.47], Tebuconazole (1) [0.38], Thiophanate-methyl (1) [0.18], Trifloxystrobin (1) [0.11]

Slovakia	9 April 2015	3	Benthiavalicarb, isopropyl- (1) [0.11], Boscalid (3) [0.13-4.7], Carbendazim (1) [2.6], Chlorantraniliprole (3) [0.12-2], Fludioxonil (1) [0.65], Fluquinconazole (1) [0.16], Imidacloprid (2) [0.13-0.18], Methoxyfenozide (2) [2.2-2.8], Myclobutanil (3) [0.3-0.7], Penconazole (2) [0.091-1.5], Pirimicarb (1) [0.4], Thiophanate-methyl (1) [0.48]
Spain	27 March 2015	1	MCPA (1) [0.79], Mecoprop (MCPP) (1) [0.3],
Switzerland	2-14 April 2015	6	Atrazine (1) [0.059], Terbuthylazine (1) [0.092]

Table 6: Detected pesticides in water samples collected from or adjacent to apple orchards. Pesticides are ordered alphabetically with the type of pesticide, number and percentage of samples in which they were found, together with the country of origin and overall concentration or concentration range.

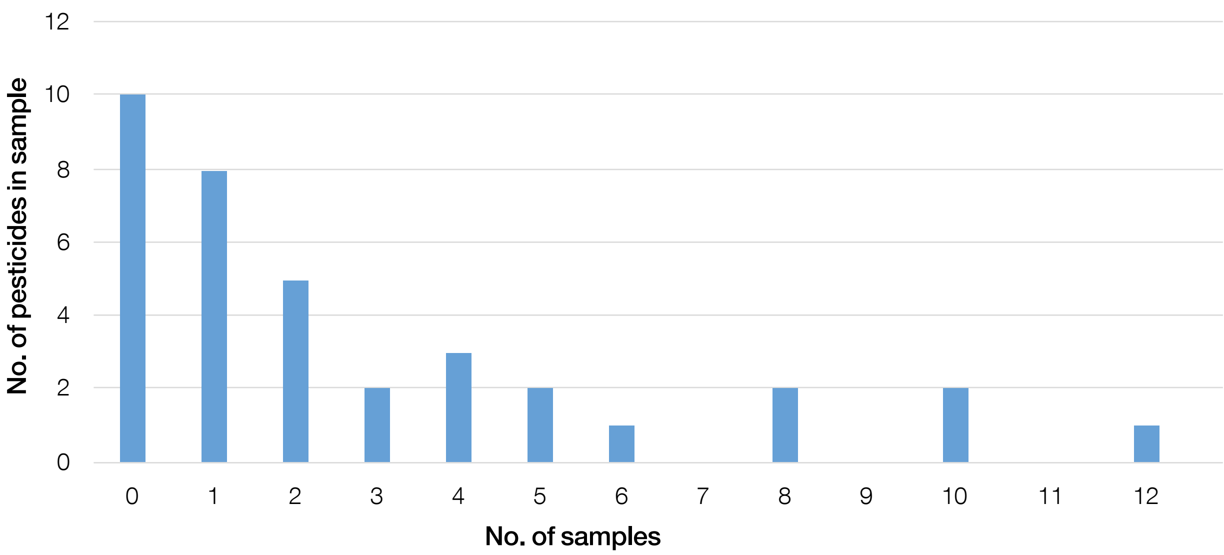
Pesticide	**Class/ type**	**Frequency of detection in water samples**		**Countries in which found (number of samples) [concentration range in µg/l]**
		Samples	**% samples**	
2,4-D	H	2	6	France (2) [0.62-7.8]
Acetamiprid	I (neo)	4	11	France (3) [1.4-12], Poland (1) [0.07]
Atrazine	H	1	3	Switzerland (1) [0.059]
Benthiavalicarb, isopropyl-	F	1	3	Slovakia (1) [0.11]
Boscalid	F	14	40	Austria (1) [0.069], Belgium (1) [1.6], France (3) [0.16-15], Greece (1) [3.3], Italy (1) [0.31], Netherlands (2) [0.08-0.084], Poland (2) [3.5-23], Slovakia (3) [0.13-4.7]
Bupirimat	F	1	3	Italy (1) [0.59]
Buprofezin	I	1	3	Italy (1) [0.39]
Carbendazim	F	5	14	Italy (1) [0.19], Netherlands (1) [0.05], Poland (2) [0.14-0.34], Slovakia (1) [2.6]
Chlorantraniliprole	I	14	40	France (3) [0.084-1.5], Germany (4) [0.07-0.63], Greece (1) [1.1], Netherlands (1) [0.075], Poland (2) [0.067-0.5], Slovakia (3) [0.12-2.0]
Chloridazon	H	1	3	Belgium (1) [0.9]
Chlorpyrifos-ethyl	I (op)	4	11	Austria (1) [0.15], Italy (2) [0.16- >50], Poland (1) [0.1]
Chlorpyrifos-methyl	I (op)	1	3	Austria (1) [19]
Cyprodinil	F	2	6	Belgium (1) [0.058], Poland (1) [0.24]
Diflufenican	H	1	3	Belgium (1) [0.091]
Dimethomorph	F	1	3	Belgium (1) [0.2]
Fludioxonil	F	4	11	France (2) [0.17-0.2], Poland (1) [0.49], Slovakia (1) [0.65]

Fluquinconazole	F	1	3	Slovakia (1) [0.16]
Imidacloprid	I (neo)	3	9	Germany (1) [0.067], Slovakia (2) [0.13-0.18]
Indoxacarb	I	1	3	Poland (1) [0.37]
Isoproturon	H	1	3	Belgium (1) [0.95]
Linuron	H	1	3	Belgium (1) [1.6]
Metalaxyl	F	1	3	France (1) [0.066]
Methoxyfenozide	I	5	14	Italy (1) [0.29], Netherlands (1) [0.16], Poland (1) [1.5], Slovakia (2) [2.2-2.8]
MCPA	H	2	6	Austria (1) [0.082], Spain (1) [0.79]
Mecoprop (MCPP)	H	3	9	Netherlands (2) [0.11-0.23], Spain (1) [0.3]
Myclobutanil	F	4	11	Greece (1) [0.16], Slovakia (3) [0.3-0.7]
Oxadiazon	H	1	3	Italy (1) [>50]
Penconazole	F	4	11	France (1) [0.15], Italy (1) [1.3], Slovakia (2) [0.091-1.5]
Pendimethalin	H	1	3	Austria (1) [0.19]
Pirimicarb	I	1	3	Slovakia (1) [0.4]
Propyzamide	H	1	3	France (1) [0.1]
Pyraclostrobin	F	1	3	Poland (1) [0.47]
Pyrimethanil	F	1	3	Italy (1) [1.1]
Tebuconazole	F, P	2	6	Greece (1) [0.39], Poland (1) [0.38]
Terbuthylazine	H, M. AL	1	3	Switzerland (1) [0.092]
Tetraconazole	F	2	6	France (2) [0.12-0.24]
Thiophanate-methyl	F	3	9	Italy (1) [0.065], Poland (1) [0.18], Slovakia (1) [0.48]
Trifloxystrobin	F	1	3	Poland (1) [0.11]

Key

Al = algicide, Ar = acaricide, F = fungicide, H = herbicide, I = insecticide, M = microbiocide, P = plant growth regulator, op = organophosphate, neo = neonicintinoid

Fig. 2 Frequency of pesticides detections in water samples collected within or adjacent to apple orchards

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04

Discussion

General

These findings represent a "snapshot" of pesticide active ingredients found in soils taken from apple orchards and in water samples taken in or adjacent to orchards during April 2015. This timing coincided with the onset or early stages of blossoming. It should be appreciated that the situation with regard to pesticide residues in soils and waters could be different at different times of the year depending on whether additional pesticides are applied later on in the growing season (e.g. during fruit development) and also on the precise timing of sample collection in relation to pesticide application. Other factors which may need to be taken into account are regional climate and weather patterns through the growing season as a whole. In addition, while the soil and puddle water samples are most likely to reflect pesticides applied locally, the pesticide content of waters sampled from ditches/canals could possibly reflect pesticides applied elsewhere and mobilized via drainage waters.

The results indicate that the application of pesticides in apple orchards can lead to the presence of significant levels of residues remaining in the soil or mobilized into both standing and drainage waters. Across the entire set of 85 samples taken, residues of at least one pesticide were found in 64 samples (75% of the total). A total of 53 different pesticides were found across these 64 samples. Of all the soil samples taken, 38 of 49 (78%) contained pesticides. 26 of the total of 36 water samples (72%) also contained pesticide residues.

The fate of applied pesticides can vary. Applied pesticides can directly contaminate soils and water within the area in which they are applied, while drift during spray application can lead to the contamination of wider areas. Soil contamination can lead subsequently to pesticides and their metabolites being leached out into aquatic systems at a later date. Their precise fates will depend upon the soil adsorption properties and the properties of the pesticides themselves, including the degradation rate. Leaching through the soil may also lead to the contamination of groundwater resources, though this was not investigated in the current study. All such contamination, therefore, can result in a wide mobilization of pesticide residues and metabolites into the environment, with a variety of potential negative impacts.

Effects of the pesticides found in the apple orchards

Overall assessment

37 of the 53 pesticides found either in the soil samples from apple orchards or the water samples from within or adjacent to apple orchards, are listed on the Greenpeace Pesticide Blacklist[2], which lists substances identified as having high overall toxicities towards humans and/or wildlife. The Greenpeace Blacklist study contains a relative assessment of the overall toxicity of more than 1 000 pesticides towards humans and wildlife in 15 broad categories. It is based on databases and data inventories, such as the International Agency for the Research on Cancer[3], the EU CLP directive 1272/2008[4] and the IUPAC Footprint database[5].

Broadly, based on the aggregated toxicoligical properties of the substances, they are assigned to an Exclusion Blacklist (very high toxic properties in at least one category), an aggregated toxicity points Blacklist (high overall sum of toxic properties), a Greylist (no highly toxic properties) and a Yellowlist (not enough toxicity information for an adequate assessment).

2. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Fresh%20Deciduous%20Fruit%20Annual_Vienna_EU-27_10-28-2011.pdf
3. Die Schwarze Liste der Pestizide II, Greenpeace Germany 2010.
4. www.iarc.fr
5. Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures

32 (60%) pesticides found in the apple orchard samples are on the Exclusion Blacklist and further 5 (9%) on the aggregated Blacklist. 13 substances are on the Greylist, while a further 3 of the substances found are not listed in either the Grey or Black lists because they were thought not to be used anymore worldwide. This toxicity assessment is summarized in Fig. 3.

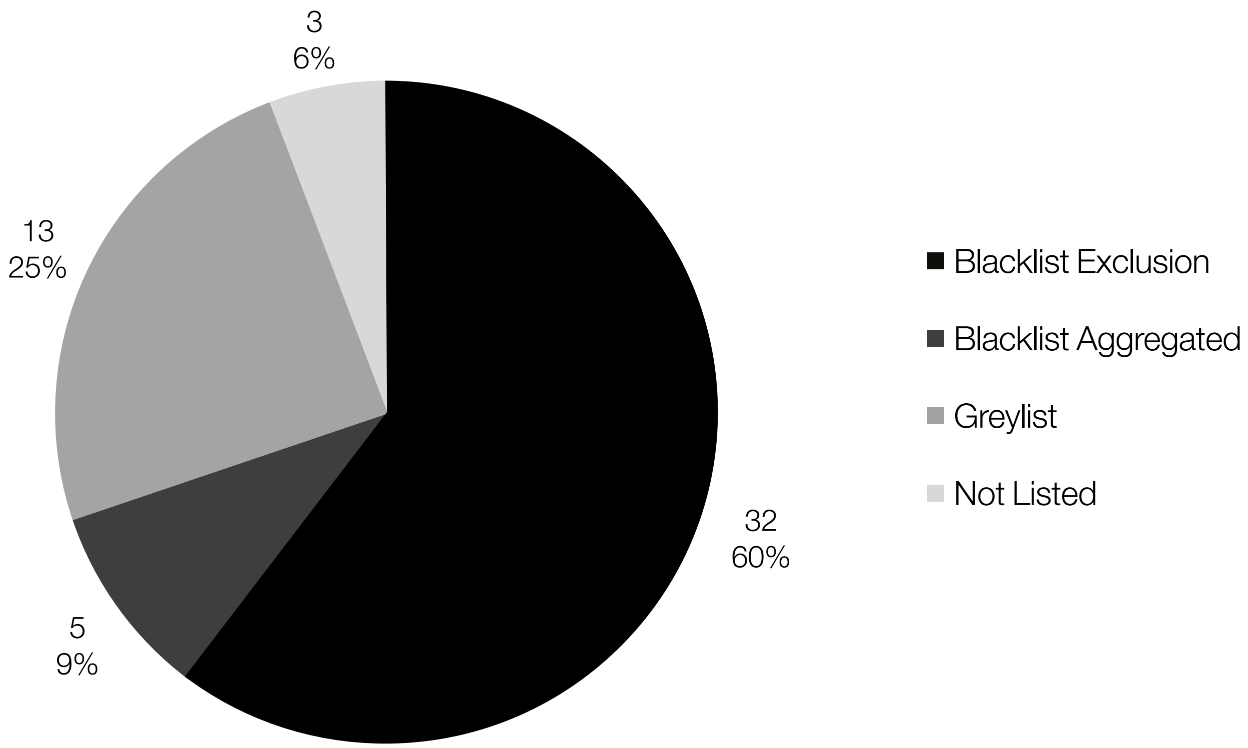

Fig. 3. Toxicity assessment of the 53 pesticides found in water and soil samples from apple orchards according to the Greenpeace Pesticide Blacklist Study1

Environmental Assessment

In a wildlife specific assessment, the effects of the 53 substances found were evaluated according to the German TLI pesticide meta-database[6]. This database is comprised of similar categories to the Greenpeace Blacklist but with more species-specific data. According to the toxicological properties of the individual substance, it is assigned up to 10 points in 5 tiers (1; 3; 5; 8, 10) in one or more of 15 categories.

Toxicity to aquatic organisms

In relation to acute aquatic toxicity towards algae, fish and water fleas *(Daphnia spp)* in the context of the TLI database outlined above, of the 38 pesticides found in the water samples, nine of them exhibit at least one count of the highest toxicity (10 points); among these are two which merit the highest toxicity count for fish, water fleas and algae. These are diflufenican and trifloxystrobin (Table 7).

6. http://www.pestizidexperte.de/tli.php; TLI = Toxic Load Indicator

Table 7: Highest aquatic toxic values of the pesticides found in the water samples (from TLI pesticide database) Toxicity is scored out of 10 points on a 5-tiered scale.

Pesticide	Algae Toxicity	Fish & Water Flea Toxicity	No. of samples
Diflufenican	10	10	1
Pendimethalin	10	8	1
Chlorantraniliprole	5	10	14
Chlorpyrifos-ethyl	5	10	4
Chlorpyrifos-methyl	5	10	1
Oxadiazon	10	5	1
Pyraclostrobin	5	10	1
Pirimicarb	1	10	1
Trifloxystrobin	10	10	1

Toxicity to soil-dwelling organisms

The toxicity of pesticides to soil-dwelling organisms is not easy to evaluate since soil organism toxicity data are relatively scarce. Here, the acute earthworm toxicity from the TLI pesticide database is used as a comparator. According to these data, of the 37 pesticides found in the soil samples, carbendazim has the highest possible earthworm toxicity count (10 points). Nearly all the other pesticides found (34) have moderate or unknown earthworm toxicity (5 points).

Toxicity to bees

Eight of the pesticides found in the soil or water samples have a very high bee toxicity (10 out of 10 points) (Table 8).

Pesticides with Endocrine Disrupting Potential

The TLI database also lists endocrine disrupting chemicals (EDC) based on data from the European Commission (EC 2000, 2004, 2007) and on the criteria incorporated in the Pesticide Directive 1107/2009 (EC 2009).

Four of the pesticides found in the apple orchard samples achieve the highest possible rating for endocrine disrupting potential (10 points). These are: Atrazine, DDT, Deltamethrin and Linuron. Another seven pesticides found achieve second tier rating as follows:

2,4-D, Carbendazim, Dieldrin, Endosulfan, Endrin, Iprodione, Triadimenol (8 points)

Table 8. Highest bee toxic values (10 points out of 10 points) of the pesticides found in soil and water samples (from TLI pesticide database)

Pesticide
Chlorpyrifos-ethyl
Chlorpyrifos-methyl
Deltamethrin
Dieldrin
Endrin
Etofenprox
Imidacloprid
Indoxacarb

Table 9: Pesticides found in soil samples from apple orchards with very high persistence (10 out of 10 points from the TLI pesticide database)

Substance	
Boscalid	Flusilazole
Chlorantraniliprole	Imidacloprid
Cyprodinil	Methoxyfenozide
DDT	Myclobutanil
Dieldrin	Oxadiazon
Difenoconazole	Penconazole
Diflufenican	Pirimicarb
Endrin	Tebuconazole
Fludioxonil	Tetraconazole
Fluquinconazole	Thiabendazole

Table 10: Pesticides found in soil samples from apple orchards with very high leaching potential (10 out of 10 points from the TLI pesticide database)

Pesticide
Boscalid
Chlorantraniliprole
Imidacloprid
Methoxyfenozide
Myclobutanil

Persistence in the Environment

An important property of pesticides and other chemicals is their persistence, i.e. how long the substance remains in the environment before breaking down. In the TLI database, persistence values are available based on soil half-life values. 20 of the pesticides found in the soil samples have the highest persistence counts (10 out of 10 points) (Table 9). A high environmental impact of a substance can be inferred for a specific substance if it exhibits a combination of high (aquatic) toxicity with high persistence. This combination of properties is shown by diflufenican (found in 1 water sample), chlorantraniliprole (14 samples), oxadiazon (1 sample) and pirimicarb (1 sample).

Leaching Potential

Another important property in determining the environmental impact of a pesticide is the leaching potential from soil. The less readily a substance binds to soil, the more easily it can be leached out of the soil into aquatic systems. 5 of the pesticides found in the orchard soil samples have a very high leaching potential count (10 out of 10 points) in the TLI pesticide database (Table 10).

Approval and authorization status of the detected pesticides in the EU

In the European Union, pesticide use is restricted to those which have been approved. Exceptionally, EU Member states can authorize the use of chemicals which are not approved in response to specific threats to crops and within a limited time frame (e.g. for 120 days).

Of the 53 pesticides found in the soil and water samples, 46 are approved within the EU[8]; the approval status for three of these (fenhexamid, isoproturon and thiabendazole) will end this year. Seven pesticides are not approved.

The most frequently found pesticides which are not approved were: DDT (as the summed metabolites DDE and DDD), found in 13 soil samples (26% of all soil samples), carbendazim (possibly formed as a metabolite of thiophanate-methyl) in four soil samples (8% of all soil samples) and five water samples (14% of all water samples), and endosulfan (as the highly persistent metabolite endosulfan sulphate) in three soil samples (6% of all soil samples) (Table 11).

The frequent detection of DDT (as DDD and DDE) in the soil samples is not surprising because of the high persistence of these metabolites, which can reflect DDT use several decades ago. Similar considerations apply to the detection of Endrin and Dieldrin, which are highly persistent organochlorines and whose detection also probably reflects historical use.

Carbendazim is authorized for use in Austria, Spain, Poland, Portugal, Romania and Great Britain[7]. However, it was also found in samples from in Belgium, Germany, Italy and Netherlands. This is probably due to the formation of carbendazim as a metabolite of the approved active ingredient thiophanate-methyl[9].

Endosulfan is authorized for use in Spain[8]. It is unlikely that the three detections of endosulfan in Austria, Italy and Switzerland were, however, the result of illegal use. It was detected as the persistent metabolite endosulfan sulphate (see Annex B) implying that it was present due to historical use of the parent compound.

Table 11: Pesticides not approved in the EU found in soil and water samples

Pesticide	Found in soil samples		Countries in which found (no. of samples) [mg/kg]	Found in water samples		Countries in which found (no. of samples) [µg/l]
	n	%		n	%	
Atrazine	0	0		1	3	Switzerland (1) [0.059]
Carbendazim	4	8	Belgium (1) [0.11], Germany (2) [0.072-0.13], Italy (1) [0.57]	5	14	Italy (1) [0.19], Netherlands (1) [0.05], Poland (2) [0.14-0.34], Slovakia (1) [2.6]
DDT (as DDD and DDE)	13	26	France (2) [0.015-0.023], Germany (2) [0.083-0.184], Hungary (3) [0.015-0.11], Neth-erlands (4) [0.036-0.4], Poland (2) [0.019-0.092]	0	0	-
Dieldrin	1	2	Greece (1) [0.072]	0	0	-
Endosulfan (as Endosul-fan sulphate)	3	6	Austria (1) [0.076], Italy (1) [0.03], Switzerland (1) [0.03]	0	0	-
Endrin	1	2	Austria (1) [0.04]	0	0	-
Flusilazol	2	4	Poland (2) [0.05-0.23]	0	0	-

7. EU Pesticide Database, http://ec.europa.eu/sanco_pesticides/public/index.cfm?event=homepage& language=EN; Access on May, 5th, 2015
8. EU pesticide authorization status under http://ec.europa.eu/sanco_pesticides/public/index.cfm? event=activesubstance.detail&language=EN&selectedID=1080
9. Regional temporary (e.g. 120 days) exceptions not considered

Legal Pesticide Limits in Waters in the EU

EU Water Framework Directive

With EU Directive 2000/60/EC, Environmental Quality Standards are defined for priority water contaminants[10]. Of these substances, three were found in the apple orchard water samples: atrazine, chlorpyrifos-ethyl and isoproturon. In the 6 samples in which these pesticides were found, the levels in 5 of them exceeded the quality standard limits, in one case exceeding the maximum EQS[11] : This was the case for a single water sample from Italy containing chlorpyrifos-ethyl at more than 50 µg/l[12] (Table 12).

Table 12: Pesticides detected in water samples from apple orchards listed as priority water contaminants (EC 2008/105). Exceedances of Average (red), Maximum (orange) quality standard

Pesticide	No. of samples detected in	Countries in which found (no. of samples) [µg/l]	Environment quality standard (average/max) in µg/l
Atrazine	1	Switzerland (1) [0.059]	0.6 / 2.0
Chlorpyrifos-ethyl	4	Austria (1) [0.15] Italy (2) [0.16; >50] Poland (1) [0.1]	0.03 / 1.0
Isoproturon	1	Belgium (1) [0.95]	0.3 / 1.0

10. DIRECTIVE 2013/39/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy
11. The Water Framework directive defines a maximum value and a lower, annual average limit
12. Exceeding the maximum detectable value of the laboratory

Mixture effects

Pesticides do not normally occur in the environment as isolated single substances, but commonly as mixtures. The presence of mixtures of pesticides in the samples is strikingly illustrated by this study, with up to 13 pesticides found in a single soil sample (Fig. 1) and 12 in a single water sample (Fig. 2). Accordingly, both terrestrial and aquatic habitats could be contaminated by several substances either simultaneously or, more likely, over a short time frame with successive applications of different pesticides.

A previous Greenpeace study has reviewed some of the scientific literature on the combined effects of pesticide mixtures on humans and natural systems[13]. For natural systems, additive (1 + 1 = 2) and synergistic effects (1 + 1 ≥ 2) were reported for certain pesticides. Among these, the following underlined substances were found in the apple orchard samples:

- The acaricides tau-Fluvalinate and coumaphos used in beehives showed an increase in toxicity to bees when the bees had previously been contaminated with the other pesticide.
- The toxicity to earthworms of cypermethrin and chlorpyrifos-ethyl was much higher for the mixture of both as compared to the single substances, even for chronic effects.
- A mixture of insecticides (containing endosulfan and chlorpyrifos (-ethyl)) killed 99% of one frog species, but not a different species
- Chlorothalonil and atrazine showed synergistic impairment of reproduction in water fleas.
- Exposure to a mixture of imidacloprid and thiacloprid resulted in a synergistic impact on the number of neonate (newborn) water fleas, while showing an additive effect for the body length.
- Addition of atrazine (10 µg/l) increased the toxicity of terbufos to water fleas in comparison with the individual administration of terbufos.

Combined exposures of pesticides can have unexpected effects compared to the effects of exposure to single active ingredients. Effects of combinations of pesticides may be additive, or in some cases they may be greater than additive. Testing of pesticides during the authorization process, however, is always performed with the single substance. Formal methods for evaluating mixture effects are under discussion within Europe, but a timeline for legislation has not yet been set. In any case, the evaluation of the toxicity of mixtures is technically a challenging task. Considering the maximum of 13 pesticides found in one soil sample, then taking just 5 at a time leads to a total of 1,287 combinations of pesticides which would need to be individually assessed. Taking two individual pesticides at a time leads to 78 combinations which need to be considered.

13. Mehrfachbelastungen durch Pestizide auf Mensch und Umwelt, Study for Greenpeace Germany, Hamburg 2012.

05

Annex

Analytical Methodologies

Annex A

Pesticides in water/ GC

An internal standard was added to 200 ml of the water sample and filtered through a SPE cartridge, in order to adsorb the pesticides onto the cartridge. Immediately, the cartridge was washed three times with 300 µl acetone. After drying the solution, the residue was absorbed in 300 µl acetone and the internal standard for PBCs was added directly. The quantification resulted from recovery over two limits of quantification (0.1 – 1 µg/l). All solutions were measured by GC-MS and FPD.

Instrument: GC AGILENT 7890
column: 15 m FS-Kapillare HP-5MS /Ø 0.250 mm

Pesticides in water/ LC

2 ml of the water sample was filtered using a membrane filter. An internal standard and 50 µl methanol were added to 850 µl of the filtrate. The quantification resulted from recovery over two limits of quantification (0.1 – 1 µg/l). All solutions were measured by LC-MS/MS (ESI-Modus).

Instrument: AB Sciex 5000 Tandem Mass spectrometer
column: Synergi 4 µm Fusion-RP 80A, 100 x 2.0 mm

Acid pesticides in water/LC

2 ml of the water sample were filtered using a membrane filter. An internal standard and 50 µl methanol were added to 850 µl of the filtrate. The quantification resulted from recovery over two limits of quantification (0.1 – 1 µg/l). All solutions were measured by HPLC-MS/MS (ESI-Modus).

Instrument: AB Sciex 5000 Tandem Mass spectrometer
column: Gemini C6-Pehnyl 3 µm, 50 x 2.0 mm

Pesticides in soil/ GC

10 ml ethylacetate were added to 5 g of a dry, homogenized soil sample. For extraction, the sample was mixed for 30 minutes. After centrifugation for 2 minutes, the internal standard and the PCB standard were added directly to 1 ml of the clear extract.

Instrument: GC AGILENT 7890
column: 15 m FS-Kapillare HP-5MS /Ø 0,250 mm

Pesticides in soil/ LC

20 ml ethylacetate and an internal standard were added to 5 g of a dry, homogenized soil sample. For extraction, the sample was mixed for 60 minutes. 200 µl of the overlap were dried completely and 1 ml of methanol/ water (1:1) were added. The quantification was calculated from the recovery achieved of the internal standard.

Instrument: AB Sciex 5000 Tandem Mass spectrometer
column: Synergi 4 µm Fusion-RP 80A, 100 x 2.0 mm

Acid pesticides in soil/LC

5 g of a dry, homogenized soil sample were mixed with internal standard, 20 ml acetone and 500 µl concentrated hydrochloric acid. After mixing for 60 minutes and centrifugation for 2 minutes, 2 ml of the liquid extract were dried completely by using nitrogen. Afterwards, 500 µl methanol and 500 ml water were added to the residue which was measured by LC-MS/MS.

Instrument: AB Sciex 5000 Tandem Mass spectrometer
column: Gemini C6-Pehnyl 3 µm, 50 x 2.0 mm

Annex B

Pesticides summed from the applied product and/or metabolites as described by the IUPAC Pesticide Properties Database (http://sitem.herts.ac.uk/aeru/iupac/index.htm)

Carbendazim: reported as carbendazim, although it is a possible metabolite of both benomyl and thiophanate-methyl

DDT: sum of the metabolites DDD, p, p'- and DDE, p, p'-

Endosulfan: reported as the metabolite endosulfan sulfate

Pirimicarb: reported as the sum of pirimicarb, and the metabolites pirimicarb-desamido-desmethyl, pirimicarb-desmethyl and pirimicarb-desmethyl-formamido.

Terbuthylazine: reported as the sum of terbuthylazine, and the metabolites terbuthylazine-2-hydroxy and terbuthylazine-desethyl

References

EC (2000): Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption – preparation of a candidate list of substances as a basis for priority setting. European Commission, Delft.

EC (2004): Commission Staff Working Document SEC (2004) 1372 on implementation of the „Community Strategy for Endocrine Disrupters – a range of substances suspected of interfering with the hormone systems of humans and wildlife" (COM (1999) 706). Europäische Kommission, Brüssel.

EC (2007): Commission Staff Working Document on the implementation of the „Community Strategy for Endocrine Disrupters – a range of substances suspected of interfering with the hormone systems of humans and wildlife" (COM (1999) 706), (COM (2001) 262) and (SEC (2004) 1372), (SEC(2007)1635). European Commission (EC), Brussels, 30.11.2007.

EC (2009): Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC

How Ecological Solutions can Bloom

Ecological Pest Management and Alternative Control for the Most Important Diseases and Pests in Apples

Contents

01

Introduction

Apples can be affected by a wide variety of pests and diseases. Numerous insect orchard pests and fungal and bacterial orchard diseases have been identified and described, together with other agents which cause spoilage of stored fruit (FSA 2006; Peck & Merwin 2009). Apples are an important commodity crop both in Europe and worldwide and are traded as fresh fruit, pulped fruit and as concentrate. The EU contributes around one sixth of the total global apple production (US Apple Association 2011), and a little over 40% of global apple exports (2012 data, WAPA 2015), with Poland, Italy, France, Germany, Hungary and Spain being particularly important producers (FSA 2006).

Given the wide variety of pests, diseases and spoilage organisms affecting apple and other fruit crops, pesticide use is both fairly widespread and fairly intense (see: Eurostat 2007). Evidence for this is also furnished by the results for soil and water samples taken in (or, in the cases of some water samples, immediately adjacent to) orchards in the early part of the growing season and reported in the first part of this document. Substantial quantities of both insecticides and fungicides are reported as being used on apple trees (Eurostat 2007), reflecting the pests and diseases which particularly affect these crops. As a result, apples have been the focus of consumer concerns in relation to the pesticide residues which can be present in marketed products. The most recent (2013) results from routine EU wide surveillance monitoring of marketed apples detected 55 different pesticides in 1,610 apple samples. Two thirds of these samples contained detectable residues of one or more pesticides. Multiple residues were found in 46% of samples and, in 6% of samples, six or more residues were detected. In 1% of the samples analysed, Maximum Residue Levels (MRLs) for at least one of nine pesticides were exceeded (EFSA 2015).

Alongside the "point of sale" impacts of widespread pesticide use in orchards, the impacts at the "point of use" must also be considered. Pesticide resistance of the codling moth, a globally distributed pest, has been widely reported as a result of the intensive use of pesticides with similar modes of lethal action (see: Dunley & Welter 2000; Voudouris et al. 2011). Counter-intuitively, fruit tree spider mites tend to become problematic after orchards are sprayed with pesticides as a result of the suppression of natural predators, although some pesticides seem to stimulate mite populations through various mechanisms particularly if spraying is carried out in hot weather (Godfrey 2011).

In addition to these potential problems there are also more widespread possible impacts not least those on human health. Farmers and growers have been identified in the scientific literature as particularly susceptible groups due to their direct and repeated use of, and contact with, various pesticides (Allsopp et al. 2015).

Economic damage is an inevitable consequence of over-reliance on pesticides. The erosion of natural pest control, in turn, compromises processes which, across the United States alone, have been valued at some at $4.49 billion (€4.2 billion) (Losey & Vaughan 2006). Secondly, when other externalised costs are considered, the economic costs are magnified. Economic losses attributable to the application of pesticides in the US per year have been estimated at: $1.1 billion (€1 billion) for public health; $1.5 billion (€1.4 billion) for pesticide resistance; $1.4 billion (€1.3 billion for pesticide related crop losses, $2.2 billion (€2 billion) for pesticide related bird losses and $2.0 billion (€1.8 billion) for groundwater contamination (Pimentel & Burgess 2014).

What Are Pesticides?

'Pesticide' – a substance used to protect plants and animals from pests and diseases. Synthetic chemical pesticides are chemical substances or mixtures used to control pests, including insects, fungi, moulds and weed plant species. These substances are also commonly known as 'plant protection products'. They are often categorised according to the target pest, for example:

Insecticides – to control insect pests.

Herbicides – to control weeds.

Fungicides – to control fungal pests.

Together, these groups cover a very large number of individual active ingredients, formulations and brand names. Pesticides are also categorised by their chemical class – for example, organophosphorus (OP pesticides), organochlorine pesticides (OC pesticides), carbamates, neonicotinoids.

Against this background, however, there appears to be a strongly held view in some academic circles that pesticides are necessary for the future success of modern agriculture. (see: e.g. Weller et al. 2014), and it seems that this perception may be shared by many fruit growers. The intention of this report, based on a review of available literature, is to show that a wide variety of potential solutions are already available for the control of pests and diseases in apple growing without the use of pesticides. By providing this information and by illustrating the potential for the use of pesticide-free apple growing methods, it is hoped that this report will help to shift this sector of agriculture towards ecological-farming methods. Such a move involves the potential application of a diverse mix of techniques. These include agro-biodiversity based methods to increase resilience to pests and diseases, ecological management tools to combat infestations and infections in orchards and breeding methods to select for disease resistant varieties, based on modern biotechnology.

02

Smart Breeding to enhance resilience: marker assisted selection (MAS)

Many of the popular commercial apple varieties (such as Braeburn, Fuji, Gala, Pacific Rose, Pink Lady, etc.) are susceptible to the apple scab fungus (*Venturia inaequalis*). Other important diseases in commercial apples include the powdery mildew fungus (*Podosphaera leucotricha*) and the fire blight bacteria (*Erwinia amylovora*). In addition, diseases can occur during apple storage. For pesticide-free apple orchards to become a reality, apple varieties are needed that are resistant to disease, satisfy consumer preferences in terms of taste and texture and which can be stored for several months.

Apple trees take between 3 and 8 years to mature to fruiting stage depending upon the rootstock used. Accordingly, traditional breeding methods to select for particular traits, such as disease resistance, can be slow and, therefore, expensive. In addition, many traits are controlled by multiple genes (Kumar et al. 2012), which makes breeding for specific traits complex. The past 10-15 years, however, have seen a quiet revolution in apple breeding (Troggio et al. 2012). The main advance has been in the identification of "molecular markers" within the genome (DNA) of apples that correspond to particular traits. Identification of such traits, such as disease resistance, has been facilitated by the sequencing and publication of the apple genome in 2010. The identification of these markers allows apple breeders to speed up the conventional breeding process using marker assisted selection (MAS) techniques.

Marker assisted selection (MAS) is an extremely useful breeding approach that can "fast-track" the breeding of new varieties of a variety of crops, reducing the time and costs involved in bringing disease resistant varieties to market (Vogel 2014). MAS is also known as marker assisted breeding (MAB) while advanced MAS techniques are referred to as "genomic selection". All rely on the same principle of using molecular markers to track areas of the genome containing genes of interest through the conventional breeding process. This makes it easier for breeders to identify offspring that are likely to have the desired disease resistance. Importantly, MAS also makes it easier for breeders to select offspring which do not carry genetic material associated with undesirable traits such as low yield (so-called "linkage drag"). MAS, therefore, greatly assists the breeding of desired traits into new crop varieties, often with traits introduced from wild relatives or traditional varieties (Vogel 2014). MAS is not a replacement for traditional, conventional breeding techniques, but can help to make it more efficient. It is used to select offspring with the specific natural genes associated with the desired trait. It does not include the transfer of gene sequences which characterise genetic engineering techniques and does not result in a genetically modified plant.

The publication of the DNA sequence of the apple genome (Velasco et al. 2010) has greatly facilitated the use of MAS in apple breeding:

"Many genes related to disease resistance, aroma and taste, plant development and reaction to the environment have been identified and mapped to the chromosomes. …These markers are currently being used in advanced breeding programs and comparative genetic studies that should speed cultivar development. The anchored sequence of the apple genome will be a tool to initiate a new era in the breeding of this crop." (Velasco et al. 2010)

The public availability of this sequence enables molecular markers of specific traits to be more easily identified throughout the entire apple genome. The identification of markers is often time consuming and a rate-limiting step in MAS. Hence, publication of the genome promises to greatly speed up the process of breeding new varieties of apples with disease resistance traits that could prove suitable for pesticide-free cultivation.

A substantial number of major disease resistance genes have now been mapped in the apple genome, including those for scab, powdery mildew and fire blight (Kumar et al. 2012). In addition, genes conferring resistance to insect attack, including the woolly apple aphid (*Eriosoma lanigerum*), an important pest of apple trees, have also been identified (Kumar et al. 2012). Through the tracking of several molecular markers, MAS can assist in the incorporation of a variety of different resistance genes for a single disease (a process known as "gene pyramiding"). This often enables durable resistance properties to be developed. Multiple genes often confer resistance to a disease over a longer time frame than can generally be achieved by a single gene (Kellerhals et al. 2014).

Genes conferring resistance to fire blight have been identified in both wild *Malus* species and in ancient cultivated varieties. MAS potentially allows these genes to be bred into commercial varieties without transferring unwanted traits which could affect eating quality or reduce apple size (Kellerhals et al. 2014). Fire blight and scab resistant varieties of apples are being developed using MAS to help in pyramiding multiple resistance genes. These potentially give durable resistance against these diseases.

MAS can also assist in breeding apple varieties with resistance to multiple diseases (see, e.g. Kumar et al. 2012; Kellerhals et al. 2014). For example, MAS has facilitated the identification of offspring resistant to fire blight, apple scab and powdery mildew (Baumgartner et al. 2010). Such offspring can be used for further breeding to develop varieties resistant or tolerant to multiple diseases.

While some of the resistant apple varieties are still under development, other disease resistant varieties are already available (Brown & Maloney 2013; Agroscope 2015) It is expected that more apple varieties will be released over coming years with greater durability of disease resistance and with resistance to multiple diseases. Nonetheless, MAS still faces challenges such as finding the best combination of markers for pyramiding disease resistance. MAS and the resistant varieties which are produced from it cannot simply be regarded as a panacea. Even if a tree proves resistant to one or more pests, it is unlikely to prove resistant to all of them (Hinman & Ames 2011). Hence, disease resistant varieties need to be cultivated within an ecological farming framework, which helps to reduce the frequency and severity of pest and disease outbreaks and helps to avoid creating the conditions under which they are likely to occur.

© GREENPEACE / FRED DOTT · SORTING AND PACKING OF APPLES ON A SUSTAINABLE APPLE FARM IN NORTH GERMANY

03

Eco-agriculture compatible techniques for apple tree and crop protection

Soil health, fertilization and husbandry

Many aspects of apple cultivation can be influenced in ways designed to help prevent outbreaks of pests and diseases or to help manage outbreaks when they do occur. Accordingly, cultivation strategies need to be well thought through and need to consider the whole growing cycles and associated land management. Apple varieties vary in their susceptibility to diseases, while pruning practices and fertilizer applications can also influence the outbreak of disease. If the overall growing regime is optimized, then it favours the application of further innovative management techniques which might otherwise be less effective in a non-optimised system. This is particularly likely to be true where management is under an organic or eco-agricultural paradigm, where chemical inputs are not made (see: Trapman & Jansonius 2008). Accordingly, attention needs to be given to pruning practices, fertilizer applications, soil management and the use of cover crops.

Soil water management to support beneficial insects

There is evidence that management of soil water and prevention of waterlogging, among a number of factors, can favour the populations of earwigs in orchards (Helsen et al. 2004) and that poorly drained areas within a plot harbour fewer of these important predators of woolly apple aphids (*E. lanigerum)* (Helsen & Winkler 2007). It is possible that poor drainage may prevent nesting and egg –laying in the soil (Helsen & Simonse 2006).

A stable agroecosystem to benefit natural predators

The stability of the orchard environment also plays a role in encouraging populations of natural predators. The commercial life of an orchard can extend to several decades and during this time they are subject to "low" or "no-tillage" management. This stable system is disrupted when the trees are felled and replaced, or by the intensive use of pesticides, as it is done in industrial agriculture throughout the whole growing period. Although recolonisation with beneficial insects can take place from outside the orchard, it may be slow and growers may need to accelerate the process by catching and releasing pest predators into new plantings (Helsen & Winkler 2007). The management of European red mite (ERM) is also helped by a stable environment which in turn allows populations of predatory mites to develop. Organic apple growers in the US are reported to suffer problems with ERM only rarely due to the pest control methods used being relatively non-toxic to predatory mites (Foster 2014).

Role of monitoring in pest control

A key component of management of ERM and other insect pests (Foster 2014) is the use of monitoring and prediction on the basis of previous experience and the onset of conditions favourable to an outbreak at the individual orchard level (Hinman & Ames 2011). This philosophy has been translated at a National Agency level in Switzerland into a sophisticated multifactorial prediction system. By taking into account temperature, humidity and forecasted weather as well as the life-cycle of the specific pests, the SOPRA (Schadorganismen-Prognose auf Apfel) system is used in the timing, monitoring, management and control of pest outbreaks (Graf et al. 2003). Apple pests covered include rosy apple aphid, apple sawfly, smaller fruit tortrix and codling moth. A similar web-based model has also been devised for fruit growers in Washington State in the US (Jones et al. 2010).

Biological Control of Insect Pests

The principle of using natural predators of orchard pests has been widely developed. Natural predators can be encouraged by the provision of natural habitats or food resources, or populations can be directly introduced to the orchard. A range of predators have been used in the UK with the potential for others to be developed (Mason et al. 2009). *Aphelinus mali* is one of several parasitoid wasps introduced into New Zealand orchards for aphid control from the early 1920s where it quickly became established (Walker, 1989). *Anystis baccarum* is a predatory mite which can feed on the European fruit tree red spider mite and the apple rust mite, while overwintering eggs of both prey species support the predator over the winter period (Mason et al. 2009). *Anthocoris nemorum*, a flower bug, is a highly important predator, overwintering as an adult and emerging as soon as the weather is suitable and prey organisms begin to become available (Mason et al. 2009). *Platygaster demades* is an egg parasitoid of the apple leaf curling midge and it can be highly effective in controlling this pest (Sandanayaka & Charles 2006).

Companion plants and predator host plants

Companion planting involves the cultivation of plants with beneficial or repellent properties alongside the apple trees. Nitrogen fixing plants can be planted in the orchard, while a variety of other plants are attributed with the ability to repel pests and infectious diseases. Such techniques remain relatively poorly researched, however (Mayer, 2010). Another approach is to carefully control the growth of plants which can act as alternative pest hosts (Solomon et al. 1999), while other planting can encourage populations of beneficial insects to develop (Vogt & Wiegel 1999).

Another approach involves the use of agro-forestry techniques as exemplified by the Wakelyns Agroforestry project in Suffolk, UK (EURAF 2015). This involved the planting of fruit and timber trees and the cultivation of cereal crops in rotation with potatoes, squash, and pasture. The dispersal of the apple trees among the seven species of other trees planted has had a positive impact on the levels of diseases and pests. This is thought to be due to their relative spatial dispersion, coupled with the disease buffering effects of the additional tree species planted. There were also positive impacts upon disease levels in the arable crops planted.

A further approach which has been receiving attention, and which might be of benefit where apples are grown in agroforestry systems, involves encouraging birds as pest predators. In a Dutch study, birds provided with nesting boxes and foraging in various orchards, were found to contribute to suppression of caterpillar pests in orchards using IPM, though not in those using organic cultivation methods (Mols & Visser 2007).

© SHUTTERSTOCK/151842209/DICK KENNY - GREAT TIT GETS FED WITH CATERPILLAR BY CARING MOTHER

© SHUTTERSTOCK/140294200/PHOTO FUN - EXAMPLE PICTURE OF AN EARWIG - USED IN PEST MANAGEMENT

Pheromones and semiochemicals

Insect pheromones (and other semiochemical lures) can be used in various distinct ways in helping to monitor and control a variety of apple pests. (see: PAN-UK 2007). Pesticide treated pheromone traps have been used to attract and kill a variety of pests (see: El-Sayed et al. 2009) while others such as those used in codling moth control use sex pheromones to lure and "mass trap" adult male moths, or both males and females together (El-Sayed et al. 2006). By monitoring population densities, traps can also be used to help determine the timing of pesticide applications, including those compatible with organic cultivation techniques. Large scale dispensing of pheromones in order to disrupt mating in codling moths is a relatively new control tactic that can be highly successful in some orchards (Barrett et al. undated). In this technique, pheromones are dispensed on a fairly wide scale to prevent male moths from locating and mating with females (Bessin 2010). There is some evidence that chemicals used as attractants for codling moth also are effective in luring the apple clearwing moth. (Tóth et al. 2012). In addition, various chemical lures may be set with a view to attracting predatory or parasitoid insects into the proximity of crops (see: Wright et al. 2013).

Insect infective agents

Insects are prone to infections with a wide range of pathogenic organisms including viruses, bacteria and fungi. Granulosis virus, in particular, has been developed as a commercial treatment targeting early stage larvae of apple codling moth (Mahr et al. 2008). *Bacillus thuringiensis* spores[1] has been shown to be effective against some insect pests, but does not work as well on codling moth (Hinman & Ames 2011).

© GREENPEACE / EMILE LOREAUX. AGROFORESTRY PLOT WITH WALNUT AND VEGETABLES. ECOLOGICAL FARM IN FRANCE

1. Both the spores of the bacterium *Bacillus thuringiensis* and its crystalline protein are permitted in organic agriculture but are different and more specific in their toxicity than Bt proteins produced by genetically modified plants

Kaolin clay

First developed as a pest control method in the late 1990's, the use of kaolin clay as a sprayed particle film system is now widely used in the US. The spray leaves a powdery film on the trees which acts as a protective barrier to insect pests, and can also cause irritation when the particles are disturbed. In addition it makes fruit trees less recognizable as hosts to insect pests. Spraying starts after the blossom petals drop and is continued for up to eight weeks to ward off codling moth, and may be continued beyond this to deal with additional pests such as apple maggot. Pest damage is very substantially reduced during the period for which the trees remain coated, though the integrity and therefore effectiveness of the kaolin film will be reduced over time through the action of wind and rain (Hinman & Ames 2011; Caldwell et al. 2013). Systems based on kaolin clay particle film technology are regarded in the US as the closest thing to broad-spectrum insect pest control currently available to organic apple (and other fruit) growers (Hinman & Ames 2011). While in widespread use in the US, according to the Pesticides Properties database, it currently appears only to be in use in Belgium, France and Greece within Europe (see: http://sitem.herts.ac.uk/aeru/ppdb/en/Reports/2410.htm). It is registered for use against the pear pest *Psylla pyricola* and several species of fruit tree aphids (EC 2011).

Compost and plant extracts

The use of aqueous compost extracts to inhibit plant diseases has also been researched over the last two to three decades after it was found that spent mushroom compost extract was particularly effective against plant diseases (Yohalem et al. 1994). It was later found to be effective against the apple scab pathogen (Yohalem et al. 1996) and has been investigated for protective effects in a variety of crops (Sagar et al. 2009). Other similar extracts of green waste composts have also been shown to inhibit the apple scab and the grapevine downy mildew pathogenic fungi (Larbi et al. 2006). The agents present in such extracts may be able to withstand autoclaving as evidenced by the suppression of pathogenic fungus by an extract of autoclaved mushroom compost studied in Japan (Parada et al. 2011). Oil extracted from the neem tree (*Azadirachta indica*), horsetail extract (*Equisetum arvense*) have also been used for pest control in apple orchards (PAN-Europe 2007) while the use of *Quassia amara* extract has been reported for the control of apple sawfly (Psota et al. 2010). These approaches have been accepted for organic growing together with a variety of other potential techniques which have been reported in the literature (see: Caldwell et al. 2013).

04

The organic apple growers' perspective

The application of diverse pesticide free systems to apple growing can be illustrated on a practical level. Table 1 lists the most important pests and diseases affecting apples and gives indications of the non-pesticide methods available for their control and management. In ecological/organic systems for apple growing, there is an increased reliance on cultural control techniques and these can involve more effort since many pests need to be specifically targeted. Control of fungal diseases can prove particularly challenging, using cultural control methods alone and there may be a need to use organically certified treatments in order to maintain effective control of the fungi and of some insect pests.

The experiences of Danny Billens, an apple grower with 30 years experience from Oetingen, in Pajottenland, a gently sloping region in Flanders, Belgium appear to be fairly typical. He has proven that apples can grow very well with only minimal application of organically-certified pesticides, and has taken a highly pragmatic approach both with his growing and his marketing strategy. In short, he has shown that growing apples without the intensive use of chemical pesticides is possible. He prefers to fight pests in a very focused way because he knows that most organisms in his orchards are useful. The most important element in his success is his adoption of a holistic ecosytem approach, which makes his orchard more resilient to pests and diseases.

"It's not an easy job, but I can certainly make the same amount of profit as I could growing apples using pesticides".

In Danny Billens' experience the market for organic products is enormous:

"There is almost always a shortage. It's difficult to supply all year round."

Organic growers benefit when total apple production rises and, because there is no competition, Flemish and Dutch growers exchange a lot of information. This makes organic fruit growing a very innovative sector, with an extensive range of alternative pesticides, techniques and methods to control pests and diseases, says Billens. He has used nettle extract against aphids quite frequently as well as extract made from horsetail. As an organic grower he wants to affect as few organisms and animals as possible and recognises that a broad-spectrum chemical treatment also kills beneficial natural insect predators.

Even organically certified pesticides can exert a heavy toll on the environment if used too often or inappropriately. A key example is copper sulphate, used against mildew, but most commonly against scab, the most damaging apple disease. Billens uses copper sulphate, but only in spring to protect the trees from diseases, and in a dose that is ten times lower than that recommended on the package.

"For the conventional apple growers it is quite normal to use three to five kg's per hectare, as the package indicates. We only use at most 500 grammes per hectare."

In Billens' experience, alternatives for copper sulphate are scarce. In Belgium, sulphur powder combined with calcium oxide, also known as quicklime, is permitted. Billens refers to it as "Californian Porridge". Previously he made it himself, but nowadays it is on the market as a ready prepared product. He is convinced that:

"It's a clean product because it breaks down into lime, so it is also a fertilizer."

It is allowed for use between mid-March and mid-June, which is sufficient to keep scab and mildew under control.

Resilient apples

While apples have variable resistance and new techniques can help develop resistant apples more quickly, Billens considers that new varieties face barriers in the market place. While a resistant variety would be ideal:

"Big traders and supermarkets only want the usual varieties."

In the Netherlands, for example retailers prefer Elstar, in Belgium, Jonagold. The markets that organic growers rely on, however, - home sales and farmers markets - offer more possibilities for marketing other varieties of apples.

"There have been experiments for years with more robust varieties. And sometimes there is a good one. A real tasty one that is much less susceptible."

Despite the possibility of developing durable resistance, this may not last indefinitely. There is a constant need to be vigilant and to use the best methods possible to predict disease outbreaks. Billens considers that:

"Germs, especially fungi, mutate and break through the resistance sooner or later."

You notice this breakthrough from one day to another.

"All of a sudden the orchard is full of mildew. Or scab."

That's why he has his own weather station because meteorological conditions can often act as a good predictor of pest and disease problems.

"With that I can measure when a big infestation is coming so I can take action in time"

Ladybirds are the small helpers in an organic apple orchard

Billens could use a substance called Spinosad against codling moth larvae, but for Billens it works way too broadly, as it also harms beneficial organisms:

"It also kills ladybirds and earwigs, so I only use it as an emergency brake."

He could also use Spruzit, a non-synthetic insecticide based on pyrethrum but this causes similar negative impacts. Therefore, he applies this only in early spring, when there are no earwigs or ladybugs to protect the apple blossom against caterpillar damage. He prefers to use a bacterial toxin such as Bt (B. thuringiensis) as this works in a more targeted way, or a viral disease organism. These, however, have the disadvantage of breaking down under sunlight.

"These resources have improved, but every 7 to 10 days you have to repeat the application."

Fragrance to confuse pest insects

An effective new treatment for codling moth is the confusion pheromone. The fragrance to attract male insects is distributed throughout the entire orchard, so that the male cannot locate the females to mate with them.

"It works well, but especially in large orchards",

explains the apple grower, but even with large plots, the edges will still have to be treated with bacterial preparation for example, Billens has found. Natural predators of pests, such as parasitic wasps, earwigs and ladybirds are of paramount importance in an organic orchard.

Neemtree to target Rosy apple aphids

At some points in the year, many green aphids can be found on the trees. Unlike many other species of aphids, these are almost harmless, causing only some minor cosmetic damage:

"You only see a few curly leaves in some places".

Indeed, Billens welcomes green aphids in his orchard, as they feed the natural enemies. Lots of green aphids mean a lot of earwigs and ladybirds, which keep the rosy apple aphid under control.

Rosy apple aphid can become a serious problem, causing curling of leaves and the apples remain small in size. If the rosy apple aphid becomes problematic, the apple grower uses NeemAzal, an agent obtained from the neem tree (A. indica). This is fairly effective, but timing of the application is critical to its success.

Straw refuges for earwigs

Billens only uses straw refuges when necessary and only at the beginning of the season. Previously, when Billens was still developing his organic orchard, he lured earwigs with straw refuges made by putting straw into a jar in which earwigs can hide:

"The advantage is that you can move the earwigs with those jars. If earwigs are needed somewhere you can just hang the jar at that spot."

Many years ago Billens tested straw sachets with wasps and lacewings, but this didn't work as well as they tended to fly away. Nowadays, they just live in the orchard and their populations develop by themselves.

Weeds and voles

Flowers are grown in Billens' orchard in order to feed populations of beneficial insects. At the edges he sows pasture seed mixtures, and between the trees he lets dandelions, daisies, buttercups and other herbs bloom.

"Lacewings need pollen to survive. So we have to ensure that there are flowers."

Weeds are hardly a problem for Billens, except for root weeds such as nettle, thistle and sorrel. These he removes with a shovel and he keeps the tree line free with a hoe. It takes some work, but he considers it to be the best solution. At one stage he tried weed suppressing membrane as a mulch around the base of the trees, but voles, which can cause severe damage by eating the bark of the fruit trees, tended to hide underneath it out of reach of predators. Billens lets the smaller flowering weeds blossom between the rows of trees, mowing every other row. The alternate rows are not mowed until the flowers bloom again.

Less productivity but higher income

Maintaining diversity in an orchard is vital for a balanced ecosystem and, in turn, a healthy population of natural pest enemies. Competition from weeds is something an organic entrepreneur needs to balance with the need to maintain a diverse balanced ecosystem. In addition, the grower must be satisfied with what the orchard produces and not ask too much of the trees.

"If prices go down, you are sometimes tempted to demand too much of an orchard."

While more manure, for example, produces more apples per hectare it may encourage problems like canker, storage diseases or aphids:

"And one thing leads to another."

Billens explains the need to keep control of production and sales at the farm level as much as possible, a strategy that has led him to start producing apple juice on his farm to add value to his production through use of any lower quality apples. Supermarkets do not sell the lower quality apples.

"In season I can sell these apples at 70 cents per kilo to alternative markets, half the price of the first quality apples, but still a good price for me."

Thirty years ago, Billens was the first grower in Flanders to professionally cultivate organic apples. He currently has 6.5 hectares of apple orchard, one hectare with pears and half a hectare of plums and cherries. His organic shop has expanded and sells a complete range of organic products and has a bakery, run by his daughter. Billens also sells his fruit at an organic market and through organic box schemes.

Billens has demonstrated that while organic apple growers may produce fewer kilograms per hectare, they benefit from the premium prices that the products command in the market place. In addition, the lower costs of fertilizers and especially of pesticides also push the economic equation in the right direction. With a bit of clever entrepreneurship, a relatively small orchard run on eco-agriculture/organic principles will provide a good income.

Table 1: List of pests and diseases which can affect apple trees, together with a list of non-pesticide interventions possible to control or manage the disease. List of diseases taken from FSA (2006). Measures largely reproduced from DEFRA/HDC (2015). Use of organically approved pesticides are possible under some circumstances, but are not included in this listing. See also Brun & Bush (2013) for description of measures available for home-gown fruit, descriptions and images of pests and diseases.

Orchard Pest	Species Name	Damage Caused	Pesticide Alternatives
Codling moth	*Cydia pomonella*	Damage to fruit	Pheromone traps, Mating disruption, Particle film
Apple sawfly	*Hoplocampa testudinea*	Caterpillars tunnel into fruit	Quassia extract Biological control using the parasitoids *Lathrolestes ensator* and *Aptesis nigrocincta* (see: http://apples.hdc.org.uk/apple-sawfly.asp)
Winter moth	*Operophtera brumata*	Damage to foliage and buds , fruit produced drop early or mature with cork-like scars	*Bacillus thuringiensis*; Cultural control involving isolation from, or treatment of natural woodland host trees (see: http://apples.hdc.org.uk/winter-moth-additional-information.asp#link6)
Rosy Apple aphid	*Dysaphis plantaginea*	Causes leaf and fruit distortion, early ripening	Physical removal; encouraging hoverflies, earwigs, lacewings, ladybirds. Derris powder (see: http://apples.hdc.org.uk/rosy-apple-aphid.asp)
Blastobasis moth	*Blastobasis decolorella*	Damage to ripening fruits around stalk, or between touching fruits, damaging but local pest. Can cause severe damage in organic crops.	Cultural control: hand thinning to single fruit. Killing of larvae at harvest. *Bacillus thuringiensis* efficacy limited. Encourage earwigs as possible predators.
Apple blossom weevil	*Anthonomus pomorum*	Blossom damage and loss. Important pest of organic orchards	Good tree management and fertilization practices; Parasitic wasps as natural enemies, Scambus pomorum; *Syrrhizius delusorius* encouraged by not using insecticides (see: http://apples.hdc.org.uk/apple-blossom-weevil.asp)
Fruit tree red spider mite	*Panonychus ulmi*	Leaf discolouration, premature leaf fall, reduced yield	Control by the predatory mite *Typhlodromus pyri*, Cultural controls include care with new plantings, and avoiding bare earth cultivation. (see: http://apples.hdc.org.uk/fruit-tree-red-spider-mite.asp)
Common green capsid	*Lygocoris pabulinus*	Leaves and fruit affected. Cork-like blemishes on fruit	Neem extract; removal of rootstock sucker growths; weeds under tree should be moved to remove pest host plants (see: http://apples.hdc.org.uk/common-green-capsid.asp)
Apple rust mite	*Aculus schlechtentali*	Causes russet appearance around fruit stalk.	Control by the predatory mite *Typhlodromus pyri*, Cultural controls include care with new plantings, and avoiding bare earth cultivation. (see: http://apples.hdc.org.uk/apple-rust-mite.asp)

Fruit tree tortrix moth	*Archips podana*	Caterpillars feed on foliage and fruit. Important pest of organic orchards	*Bacillus thuringiensis*; Tree canopy management; encourage earwigs and anthocorid bugs as predators; Wasps parasitic on eggs, larvae and pupae. Mating disruption (see: http://apples.hdc.org.uk/fruit-tree-tortrix-moth.asp)
Summer fruit tortrix moth	*Adoxophyes orana*	Damage to fruit	Natural enemies important in organic orchards. *Bacillus thuringiensis*; Tree management, encouraging earwigs and other predators; Introduction of parasitic wasps; virus sprays; mating disruption. (see: http://apples.hdc.org.uk/summer-fruit-tortrix-moth.asp)
Rosy leaf curling aphid	*Dysaphis devecta*	Leaf curling	Tolerated in organic orchards. Encourage parasitic wasps, hoverflies, earwigs, lacewings; Fungal parasites; (see: http://apples.hdc.org.uk/rosy-leaf-curling-aphid.asp)
Woolly aphid	*Eriosoma lanigerum*	Damage to trees	Cultural control: encourage earwigs, parasitic wasps; Physical destruction of infestations (see: http://apples.hdc.org.uk/woolly-aphid.asp)
Apple-grass aphid	*Rhopalosiphum insertum*	Slight leaf curling	Tolerated in organic orchards. Cultural methods by encouraging predators through refuges and growing flowering plants to feed predators. (see: http://apples.hdc.org.uk/apple-grass-aphid.asp)
Apple leaf midge	*Dasineura mali*	Leaf rolling	Tree management, Natural predators, parasitic wasps, monitoring using pheromone traps. (see: http://apples.hdc.org.uk/apple-leaf-midge.asp)
Apple sucker	*Psylla mali*	Sucking of sap causes bud death in blossom. Most troublesome in older /organic orchards	Cultural control: encourage predatory bugs, reduction of nitrogen status. (see: http://apples.hdc.org.uk/apple-sucker.asp)
Green apple aphid	*Aphis pomi*	Leaf curl/growth reduction	Tolerated in organic orchards. Cultural control through providing food plants for predators and refuges (http://apples.hdc.org.uk/green-apple-aphid.asp)
Leafhopper	*Edwardsiana crataegi*	Speckling to leaves	Cultural control, isolation from wild leafhopper hosts, natural enemies, parasitic wasps. (see: http://apples.hdc.org.uk/leafhoppers.asp)
Mussel scale	*Lepidosaphes ulmi*	Debilitates tree, secretes honeydew	Cultural control: isolation from natural host plants, natural enemies, parasitic wasps
Apple powdery mildew	*Podosphaera leucotricha*	Reduces fruit size, loss of leaves and blossoms	Cultural controls: removal of primary inoculum by pruning, possible future control with mycoparasites (see: http://apples.hdc.org.uk/Apple-Powdery-Mildew.asp)

Apple scab	*Venturia inaequalis*	Damage to tree and fruit. Most economically important disease	Emphasis on use of scab resistant varieties in organic growing. Cultural control: elimination of overwintering scab, removal of leaf litter; Tree management, removal of wood scab. (see: http://apples.hdc.org.uk/Apple-Scab.asp)
Apple canker	*Nectria galligena*	Canker on trees; fruit rot	Cultural control, removal of cankers, burning of prunings, removal of fallen fruit, avoid high nitrogen fertilizer. Possible future biocontrol (see: http://apples.hdc.org.uk/apple-canker.asp)
Crown rot/collar rot	*Phytophthora cactorum & P. syringae*	Diseases of the scion and rootstock respectively	Cultural control: avoiding wet sites for new orchards; good soil drainage; careful rootstock selection; high grafting of trees to avoid collar rot; careful planting (see: http://apples.hdc.org.uk/Crown-Rot-and-Collar-Rot.asp)
Blossom wilt	*Monilia laxa f. sp. mali*	Loss of blossom	Blossom removal;
Sooty blotch and fly speck	*Gloeodes pomigena & Schizothyrium pomi*	Superficial blemishes result in down- grading of fruit	Cultural control: trim hedges; pruning and weed control to allow good airflow (see: http://apples.hdc.org.uk/Sooty-Blotch.asp)
Fireblight	*Erwinia amylovora*	Bacterial agent causes blossom wilt and loss of shoots on some susceptible varieties	Cultural control: removal/trimming of close-by hawthorn and susceptible ornamental plants. Avoid late flowering/secondary flowering varieties. Avoid excessive irrigation, excessive nitrogen additions (see: http://apples.hdc.org.uk/Fireblight.asp)
Silver leaf	*Chondrostereum purpureum*	"silvering" of leaves, shoot loss	Use of wound paint on major pruning/restructuring wounds, avoid pruning in wet weather, destroy affected wood by burning. (see: http://apples.hdc.org.uk/Silver-Leaf.asp)
Apple replant disease	*Pythium spp.*	Poor vigour of trees after replanting of old orchard land due to reduced root system	Cultural measures: choice of rootstock, replanting in former alleyways, lining of planting hole. (see: http://apples.hdc.org.uk/Apple-Replant-Disease.asp)

References

Agroscope (2015) Apple breeding. http://www.agroscope.admin.ch/zuechtung-spezialkulturen/05895/05898/index.html?lang=en, Retrieved 28/05/2015

Allsopp, M., Huxdorff, C., Johnston, P., Santillo, D. & Thompson, K. (2015) Pesticides and our health: a growing concern, Greenpeace Research Laboratories, UK: 54pp. URL: http://www.greenpeace.to/greenpeace/wp-content/uploads/2015/05/Pesticides-and-our-Health.pdf

Barrett, B., Gleason, M., Helland, S., Babadoost, M. & Weinzierl, R. (undated) Codling moth management in apple. USDACM Bulletin, Publ. US Department of Agriculture: 6pp. URL: http://www.public.iastate.edu/~appleipm/appleIPMMod/doc/USDACMBulletin.pdf, Retrieved 02/05/2015

Bessin, R. (2010) Codling Moth. ENTFACT 203. Publ. University of Kentucky URL: http://www2.ca.uky.edu/entomology/entfacts/entfactpdf/ef203.pdf, Retrieved 02/06/2015

Brun, C.A., & Bush, M.R. (2013) Organic pest and disease management in home fruit trees and berry bushes. Report EM066E publ. Washington State University Extension Publ. WSU/USDA: 27pp. URL: http://cru.cahe.wsu.edu/CEPublications/EM066E/EM066E.pdf, Retrieved 05/06/2015

Baumgartner, I., Franck, L., Silvestri, G., Patocchi, A., Duffy, B., Frey, J. & Kellerhals, M. (2010) Advanced strategies for breeding fire blight resistant high quality apples. Proceedings of the 14th International Conference on Organic Fruit Growing 2010. URL: http://www.ecofruit.net/2010/4_RP_I_Baumgartner_L_Franck_G_Silvestri_et_al_S31bis37.pdf, Retrieved 29/05/2015

Brown, S.K. & Maloney, K.E. (2013) An update on apple cultivars, brands and club-marketing. New York State Horticultural Society, New York Fruit Quarterly: Spring 2013 http://www.nyshs.org/fq.php Retrieved 29/05.15, Retrieved 29/05/2015

Caldwell, B., Sideman, E., Seaman, A., Shelton, A. & Smart, C. (2013) Resource guide for organic insect and disease management. 2nd edn. Publ. New York State Agricultural Experiment Station (NYSAES): 210pp. URL: http://web.pppmb.cals.cornell.edu/resourceguide/pdf/resource-guide-for-organic-insect-and-disease-management.pdf, Retrieved 02/06/2015

DEFRA/HDC (2015) Apple best practice guide. Publ. UK Department of Environment, Food and Rural Affairs/Horticultural Development Company URL: http://apples.hdc.org.uk/, Retrieved 05/06/2015

Dunley, J.E., & Welter, S.C. (2000) Correlated cross-resistance in azinphosmethyl resistant codling moth (Lepidoptera: Tortricidae). Journal of Economic Entomology 93(3): 955-962.

EC (2011) Final report on plant protection products. Expert group for technical advice on organic production (EGTOP) Publ. Directorate-General for Agriculture and Rural Development. EGTOP/3/2011. 30pp. URL: http://ec.europa.eu/agriculture/organic/eu-policy/expert-advice/documents/final-reports/final_report_egtop_on_plant_protection_products_en.pdf, Retrieved 05/06/2015

EFSA (2015) The 2013 European Union report on pesticide residues in food. Scientific report of EFSA. Publ. European Food Safety Authority, Parma, Italy: 169pp. URL: http://www.efsa.europa.eu/en/efsajournal/doc/4038.pdf, Retrived 29/05/2015

El-Sayed, A.M., Suckling, D.M., Byers, J.A., Jang, E.B. & Wearing, C.H. (2009) Potential of "Lure and Kill" for long-term pest management and eradication of invasive species. Journal of Economic Entomology 102: 1815-1835.

El-Sayed, A.M., Suckling, D.M., Wearing, C.H., and Byers, J.A. (2006). Potential of mass trapping for long-term pest management and eradication of invasive species. Journal of Economic Entomology 99: 1550-1564.

EURAF (2015) Featured Farm: Wakelyns Agroforestry- A diverse organic silvoarable system in the UK. European Agroforestry Association Newsletter No. 10 March 2015. URL: https://euraf.isa.utl.pt/newsletters/newsletter_10#p3, Retrieved 01/06/2015

Eurostat (2007) The use of plant protection products in the European Union, Data 1992-2003. Eurostat Statistical Books, Publ. Office for Official Publications of the European Communities, Luxembourg: 222pp. URL: http://ec.europa.eu/eurostat/product?code=KS-76-06-669&language=en Retrieved 29/05/2015

Foster, R.E. (2014) Fruit insects; European red mite management. Purdue University Extension. Report E-258-W: 6pp. URL: http://extension.entm.purdue.edu/publications/E-258.pdf, Retrieved 01/06/2015

FSA (2006) Pesticide residue minimisation crop guide: Apples. Published: Food Standards Agency, UK: 54pp. URL: http://www.food.gov.uk/sites/default/files/multimedia/pdfs/cropguideappledec06.pdf, Retrieved 29/05/2015

Godfrey, L.D. (2011) Spider mites. Pest notes publication 7405. Publ. University of California Statewide Integrated Pest Management Program University of California, Davis, CA 95616: 4pp. URL: http://www.iobc-wprs.org/pub/bulletins/bulletin_2007_30_04_abstracts.pdf, Retrieved 30/05/2015

Graf, B., Hopli, H. & Hohn, H. (2003) Optimising insect pest management in apple orchards with SOPRA, IOBC/WPRS Bulletin 26: 43-50.

Helsen, H., Trapman, M., Polfliet, M. & Simonse, J. (2004) Presence of the common earwig Forficula auricularia L. in apple orchards and its impact on the woolly apple aphid Eriosoma lanigerum (Haussmann). Proceedings of the International Workshop on Arthropod Pest Problems in Pome Fruit Production Lleida (Spain) 4 – 6 September, 2006. URL http://www.iobc-wprs.org/pub/bulletins/bulletin_2007_30_04_abstracts.pdf Retrieved 01/06/2015

Helsen H. & Simonse J. (2006) Oorwormen helpen de fruitteler. Fruitteelt 96(16): 14-15.

Helsen, H. & Winkler, K. (2007) Oorwormen (Dermaptera) als belangrijke predatoren in boomgaarden, Entomologische Berichten 67(6): 275-277.

Hinman, T. & Ames, G. (2011) Apples: organic production guide. Publ. The National Sustainable Agriculture Information Service (ATTRA) Report IP020: 40pp. URL: http://www.ucanr.org/sites/placernevadasmallfarms/files/112366.pdf, Retrieved 03/06/2015

Jones, V.P., Brunner, J.F., Grove, G.G., Petit, B., Tangren, G.V. & Jones, W.E. (2010) A web based decision support system to enhance IPM programs in Washington tree fruit. Pesticide Management Science 66: 587-595 URL: http://onlinelibrary.wiley.com/doi/10.1002/ps.1913/epdf, Retrieved 01/06/2015

Kellerhals, M., Baumgartner, I.O., Schütz, S. & Patocchi A. (2014) Challenges in breeding high quality apples with durable disease resistance. Proceedings of the 16th International Conference on Organic Fruit Growing 2014. URL: http://www.ecofruit.net/2014/2RP_Kellerhals_breeding_p15-21.pdf, Retrieved 29/05/2015

Kumar, S., Bink, M.C.A.M., Volz, R.K., Bus, V.G.M. & Chagné, D. (2012) Towards genomic selection in apple (Malus × domestica Borkh.) breeding programmes: prospects, challenges and strategies. Tree Genetics & Genomes 8: 1-14.

Larbi, M., Gobat, J.-M. & Fuchs, J.G. (2006) Inhibition of the apple scab pathogen Venturia inaequalis and the grapewine downy mildew pathogen Plasmopara viticola by extracts of green waste compost. In: Kraft, Eckhard; Bidlingmaier, Werner; de Bartoldi, Marco; Diaz, Luis F. and Barth, Josef (Eds.) ORBIT 2006 : Biological Waste Management. From Local to Global; Proceedings of the International Conference ORBIT 2006. Verlag ORBIT e.V., Weimar, chapter Part 2: 529-537. URL: http://www.biophyt.ch/documents/ORBIT2006_%20Larbi_%20et_al.pdf, Retrieved 02/06/2015

Losey, J.E. & Vaughan, M. (2006) The economic value of ecological services provided by insects. BioScience 56: 311–323.

Mahr, D.L., Whitaker, P. & Ridgway, N. (2008) Biological control of insects and mites: An introduction to beneficial natural enemies and their use in pest management. Publ. University of Wisconsin Co-operative Extension Publishing, Madison WI: 110pp. URL: http://learningstore.uwex.edu/Assets/pdfs/A3842.pdf, Retrieved 02/05/2015

Mason P.G., Gillespie D.R. & Vincent, C. (Eds.) (2009) Proceedings of the Third International Symposium on Biological Control of Arthropods. Proceedings of the Third International Symposium on Biological Control of Arthropods. Christchurch, New Zealand, 8-13 February 2009, United States Department of Agriculture, Forest Service, Morgantown, WV, FHTET-2008-06: 636pp.

Mayer, D. (2010) The complete guide to companion planting, Atlantic Publishing Group, Inc. Ocala, Florida US.

Mols, C.M.M. & Visser, M.E. (2007) Great tits (Parus major) reduce caterpillar damage in commercial apple orchards. PLoS ONE 2(2): e202. doi:10.1371/journal.pone.0000202

PAN-UK (2007) Crop factsheet: apples- conventional, IPM and organic. Pesticide News. Publ. Pesticides Action Network-UK, June 2007: 18-21. URL: http://www.pan-uk.org/pestnews/Issue/pn76/pn76%20p18-21.pdf, Retrieved 02/06/2015

PAN-Europe (2007) State of the art Integrated Crop Management and organic systems in Europe with particular reference to pest management: Apple production. Publ. Pesticides Action Network Europe: 21pp. URL: http://www.pan-europe.info/Resources/Reports/Apple_production_review.pdf, Retrieved 09/06/2015

Parada, R.Y., Murakami, S., Shimomura , N., Egusa, M. & Otani, H. (2011) Autoclaved spent substrate of hatakeshimeji mushroom (Lyophyllum decastes Sing.) and its water extract protect cucumber from anthracnose. Crop Protection 30: 443-450

Peck, G.M. & Merwin, I.A. (2009) A growers guide to organic apples. NYS IPM Publication no. 223. Publ. New York State Department of Agriculture and Markets and the Department of Horticulture, Cornell University: 64pp. URL: http://nysipm.cornell.edu/organic_guide/apples.pdf Retrieved 05/06/2015

Pimentel, D. & Burgess, M. (2014) Environmental and economic costs of the application of pesticides primarily in the United States. Chapter 2 in: Pimentel, D & Reshin, R [eds] Integrated Pest Management, Publ. Springer Science & Business Media, Dordrecht: 47-72.

Psota, V., Ourednikova, J. & Falta, V. (2010) Control of Hoplocampa testudinea using the extract from Quassia amara in organic apple growing. Horticultural Science (Prague) 37: 139-144. URL: http://www.agriculturejournals.cz/publicFiles/29361.pdf, Retrieved 04/06/2015

Sagar, M.P., Ahlawat, O.P., Raj. D., Vijay, B. & Indurani, C. (2009) Indigenous technical knowledge about the use of spent mushroom substrate. Indian Journal of Traditional Knowledge 8: 242-248. URL: http://nopr.niscair.res.in/bitstream/123456789/3962/1/IJTK%208%282%29%20242-248.pdf, Retrieved 02/06/2015

Sandanayaka, W.R.M. & Charles, J.G. (2006) Host location and ovipositional behavior of Platygaster demades Walker (Hymenoptera: Platygastridae) and egg parasitoid of apple and pear leaf curling midges. Journal of Insect Behaviour 19(1): 99-113.

Solomon M., Fitzgerald J. & Jolly R. (1999) Artificial refuges and flowering plants to enhance predator populations in orchards. IOBC-WPRS Bulletin 22: 31–37.

Tóth, M., Landolt, P., Szarukán, I., Szólláth, I., Vitányi, I., Pénzes, B., Hári, K., Jósvai, J. K. & Sándor, K. (2012) Female-targeted attractant containing pear ester for Synanthedon myopaeformis. Entomologia Experimentalis et Applicata 142: 27-35.

Trapman, M. & Jansonius, P.J. (2008) Disease management in apple orchards is more than applying the right product at the correct time. Proceedings of the 13th International Conference on Organic Fruit Growing: 16-22. URL: http://www.ecofruit.net/2008/016-022.pdf, Retrieved 01/06/2015

Troggio, M., Gleave, A., Salvi, S., Chagné, D., Cestaro, A., Kumar S., Crowhurst R.N. & Gardiner, S.E. (2012) Apple, from genome to breeding. Tree Genetics & Genomes 8: 509–529.

Vogel, B. (2014) Smart breeding: the next generation. Publ. Greenpeace International, Amsterdam: 59pp. URL: http://www.greenpeace.org/international/Global/international/publications/agriculture/2014/468-SmartBreeding.pdf, Retrieved 29/05/2015

Vogt, H., & Weigel, A. (1999) Is it possible to enhance the biological control of aphids in an apple orchards by flowering strips? Integrated Plant Protection in Orchards. IOBCWPRS Bulletin 22: 39-46.

US Apple Association (2011) Production and utilization analysis. Publ. US Apple Association, Vienna Virginia: 42pp. URL: http://www.yvgsa.com/pdf/facts/USApple2011ProductionAnalysis.pdf, Retrieved 09/06/2015

Velasco, R., Zharkikh, A., Affourtit, J., Dhingra, A., Cestaro, A., Kalyanaraman, A. et al. (2010) The genome of the domesticated apple (Malus × domestica Borkh.). Nature Genetics 42: 833-841.

Voudouris, C.Ch., Sauphanor, B., Franck, P., Reyes, M., Mamuris, Z., Tsitsipis, J.A., Vontas, J. & Margaitopoulos, J.T. (2011) Insecticide resistance status of the codling moth Cydia pomonella (Lepidoptera: Tortricidae) from Greece. Pesticide Biochemistry and Physiology 100: 229-238.

Walker, J. T. S. (1989) Eriosoma lanigerum (Hausmann), wooly apple aphid (Homoptera: Pemphigidae). Chapter 34. In: A Review of Biological Control of Invertebrate Pests and Weeds in New Zealand 1874-1987, (P. J. Cameron, R. L. Hill, J. Bain, and W. P. Thomas, Eds.): CAB International/DSIR Entomology Division. Technical Communication 10: 197-199.

WAPA (2015) World data report: apple and pear production by country and year. Publ. World Apple and Pear Association URL: http://www.wapa-association.org/docs/2014/World_apple__pear_exports_2003-2012.xls, Retrieved 29/05/2015

Weller, S.C., Culbreath, A.K., Gianessi, L. & Godfrey, L.D. (2014) The contributions of pesticides to pest management in meeting the global need for food production by 2050. CAST Issue Paper 55. Publ. Council for Agricultural Science and Technology, Ames, Iowa November 2014: 28pp. URL: http://www.cast-science.org/file.cfm/media/products/digitalproducts/CAST_IP55_Contributions_of_Pesticid_4992B5674417F.pdf

Wright, H.L., Ashpole, J.E., Dicks, L.V., Hutchison, J. & Sutherland, W.J. (2013) Enhancing natural pest control as an ecosystem service: evidence for the effects of selected actions. NERC Knowledge Exchange Programme on Sustainable Food Production. Publ. University of Cambridge, Cambridge: 106pp. URL: file:///C:/Users/grl/Downloads/Natural%20Pest%20Control%20Synopsis%202013%20-%20FINAL.pdf, Retrieved 02/06/2015

Yohalem, D.S., Harris, R.F. & Andrews, J.H. (1994) Aqueous extracts of spent mushroom substrate for foliar disease control. Compost Science and Utilization 2: 67-74.

Yohalem, D.S., Nordheim, E.V. & Andrews, J.H. (1996). The effects of spent mushroom compost on apple scab in the field. Phytopathology 86: 914-922.

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Farming without pesticides relies on redesigning the farming system to incorporate biodiversity into the farm, in addition to applying a diversity of agronomical practices in order to prevent, rather than fight, pest damage. Greenpeace promotes pesticide-free farming, while recognising that, on occasions, farmers might need to apply some biopesticides or mineral compounds approved under organic farming (although with potentially some harm to the environment). While this is not ideal, we recognise farmers are often under high pressure to protect their crops. This underlines the urgent need for further research on improvement of ecological farming solutions.

Greenpeace is an independent campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment, and to promote peace.

This report contains of two separate publications:

An Analysis of Pesticides in European Apple Orchards

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