Synthesis report
Sustainable fruit production to minimize residues

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WP: Reduction in pesticide residues

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Synthesis findings

What are pesticide residues?

After a phytosanitary treatment, the active substances and their breakdowns may be detected on foods, at harvest time or after storage. When they occur, they have to respect the MLR, maximum limit of residues. This happens even when pesticides are applied in the right amount and at the right time. Sometimes they need to remain on the surface of the fruit or the vegetable to protect them from pests during storage and some pesticides are applied after harvest for the same purpose. Furthermore, the use of chemicals may also have an unintended impact on the environment, on water, soil, air and the whole ecosystem.

On the other hand, plant protection is crucial for securing food production in volume and quality. In the 1990s the integrated pest management (IPM) concept was developed. The definition is given by FAO : ***Integrated Pest Management (IPM)*** *means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.*

The following report is an expertise of the EUFRIN WG “Sustainable fruit production to minimize residues” based on the state of art done in twelve European countries (Belgium, Denmark, France, Germany, Italy, Lithuania, the Netherlands, Rumania, Spain, Sweden, Switzerland, United Kingdom) on the practices developed the last years to reduce the use of pesticides and limit the risk to find pesticides on fruits and in environment. The first objective is to have an overview about what is already used by the growers and what can be disseminate to the end-users in the different countries. The second objective is to point out where gaps exist and where more research is needed.

I. Best practices for reducing the use of pesticides on pome fruits

How to take a decision to manage the protection ?

The base for IPM is the **use of decision support systems**, like warning models or pheromones traps to evaluate the pest and diseases risks. The aim is to optimize the application time and treat at the right moment or stage. Apple scab and codling moth models are the most widespread, but also powdery mildew (*Podosphera leucotricha*), European fruit tree canker (*Neonectria ditissima*) and Fire Blight (*Erwinia amylovora*) can be used in some case. On pears, a warning model for Brown spot (*Stemphylium vesicarium*) is developed and optimized. Other pests and diseases models should be developed, like aphids (for the population in autumn coming back to the orchards) or storage diseases (climate condition during summer time and close to harvest).

The forecast system used today is however not problem free. It usually requires on-farm weather stations where malfunctions in the collection and transmission of data often causes lack of information and disruptions. Development of models based on using virtual weather data has great potential but development has just started.

Combined to these tools, **monitoring the orchards** during the whole seasons gives the best view of the pest and diseases situation. Furthermore, **treatment decisions** are based on different information related to the plant protection products, on damage thresholds for several pest and diseases, and taking into account the side effects of the products on environment and biodiversity.

What do we know about alternatives to protect against pest and diseases in orchards ?

In apple orchards, **four alternatives techniques** to synthetic pesticides can be qualified “already used by the growers” :

- **Mating disruption :** it involves the use of sex pheromones to prevent male insects finding females. The pheromones are chemicals produced by an insect to communicate in some way with others of the same species. Different types of mating disruption may be applied depending of the target (codling moth, tortrix moths), the dispensers and the way to distribute them in the orchard. Unless it is planned in collaboration with the neighbourhood, one limit is the size of the orchards whose area should not be less than 1 hectare.
- **Granulosis virus :** they are Baculovirus which infects codling moth larvae by ingestion. They are applied with a normal sprayer. It leads to death and may be transmitted from one generation to another. It has to be noted the apparition of resistance of the codling moth *Cydia pomonella* to the C. pomonella granulovirus and the necessity for continuous development of new granulovirus. It also opens research questions to identify the risk factors to select pest resistant strains and identify biological control agents with lower risk of efficacy loss.
- **Enclosing nets :** it’s based on the physical barrier effect of a net. The net is fixed directly on a three range or placed around the orchard combined with the hail net. Although the technique was focused on codling moth, it can also prevent bees contaminated with fire blight bacteria to enter the orchards and reduce the thinning products.
- **Mechanical weed control :** different machineries may help to manage the weeds on the tree row to avoid concurrence for water and minerals.

In general, these techniques are interesting when the insect pressure is low or when the weeds are not too developed. Except in organic farming, they generally do not completely substitute the use of synthetic insecticides or herbicides, but result in a reduction in the number of applications.

At experimental stage, we so far identified two different techniques that are currently explored :

- the **plastic cover** on the top of the tree against rain to limit the development of apple scab and also storage diseases
- the “**fixed” spraying system** with micro-sprinklers in the head of the trees. The aim is to treat as close as possible to the scab infection (depending on the active ingredients, it can be during and after infection). In comparison to preventive treatments, the number of treatments may be reduced to those who are really necessary. Another way to use the fixed spraying system could be with treatments based on plant strengtheners combined to classic chemicals to achieve a better resistance to pests and diseases.

In the first case, the whole production system has to be rethinked because of the incidence of the rain cover on micro-climate, tree water needs, pollination, fruit quality and other diseases than apple scab. In the second case, technical improvements must be found and regulatory issues have to be cleared.

In apple orchards, **inoculum-reduction methods** serve to reduce the primary ascospores load by eliminating some of the apple scab-infected leaves. Even if it is impossible to eradicate all the inoculum, the spore-reduction strategies are complementary to apple scab treatments. The two main methods for spore reduction are : application of urea to fallen leaves or/and shredding of leaf litter with a flail mower. Another practice is to remove infested fruits to limit the development of fungi’s like canker.

Research works were led in France in the past few decades to optimize **tree training and pruning** with the objective of growing high quality fruit while improving regularity of fruit production, especially for naturally alternate bearing cultivars. Some results have been obtained showing that these new training and pruning strategies also tend to reduce diseases and pests thus showing that training may complement crop protection improvement.

How to use synthetic and bio-control products ?

Depending of the countries, some national or regional initiatives have been started to elaborate recommendations or even **guidelines to restrict the use of some products** by :

- increasing the pre-harvest interval,
- reducing the number of applications (below legal number of applications),
- choosing active substances related to their application stage (for. ex. in autumn or the dormant season, after petal fall or before fruit set, in summer and close to harvest).

The evaluation work is done by scanning an important number of spray schedules and confronting them to the pesticides residues analyses done in the treated orchards. The initiatives could be developed and shared within the phytosanitary industry and the whole food chain. Actually these approaches are confidential and only discussed in specific advisory and producer groups, while food distribution chain are having their own demanding's to the growers. So to avoid the risk to have residues on fruits, the official pre-harvest interval of a pesticide is increased and some active substances are avoided.

Research focuses on **substitution of some active substances by products used in organic production or/and by Bio-control products** (ex. carbonates, lime sulphur, acid clay, potassium aluminium sulphate, yeasts, strengtheners, but also macro-organism like nematodes or beneficial insects.). Generally the efficacy level of each is lower than a complete chemical protection due to less persistent active substances, different mode of action, and a more complicated and less successful implementation of the product. Their use in combination is however promising and under experimentation in a systemic approach. Knowledge has to be increased on the mode of action of the bio-control products and the best way to use them. Cultivar susceptibility should also be included and the comprehension of the interaction "pests/diseases-bio-control products".

What can be done against storage diseases ?

The biggest challenge to a residues low production system will be fruit rots as these infect the fruit during the last part of the fruit development and therefore cannot be controlled before fruit set. Different **pre-harvest strategies with non-synthetic fungicides** (ex. Bicarbonate, acid clay, laminarin) did not manage to contain rot damages and economic losses, especially in region with high rain fall and high fruit rot risks.

Hot water treatments after harvest give good results against *Neofabraea* spp. ("*Gloeosporium*" or Bull's Eye Rot), but the technique must be worked out for bigger volumes and shorter treatments and adapted to the different varieties..

At a more experimental stage, the possibilities to **control storage diseases by nebulization of biological control organisms in storage rooms** are examined. It's a track to be explored, but the potential candidates are rare and research and industry should have more links to promote bio-control solutions.

And is it possible to remove residues on apples ?

Soaps, warm water, brushes, Sodium silicate, sonication on fruits in packing houses and also ozonation of the grading water have been studied for several years. The conclusion is that the concentration of the detected actives substances are reduced (from 30 to 50 % and even sometimes more with combined techniques), but the process are complex. Especially systemic products are difficult to remove because they are taken up into the fruit. The elimination of the residues is not complete and the number of residues stays the same.

II. Best practices for reducing the use of pesticides on stone fruits

One of the major phytosanitary problems is *Monilia*, especially on peach varieties with a late harvest time (from August until End of September). Therefore a **prediction model** is validated reducing from 50 up to 100 % of the fungicides treatments.

Hot water treatments applied on peaches reduce brown rot, with an efficacy index ranging from 75 to 100 %. This practice is used for organic production.

On cherries, the important damages due to *Drosophila suzukii* and the difficulties to treat close to harvest, implemented a physical method with **exclusion nets** directly on the trees.

Another physical method consists to lay **glue on the tree trunks** against earwigs. The results are very good and may replace chemical treatments.

Mating disruption and **mass trapping** are two techniques, based on chemical mediators, which are usually combined with insecticides. They are applied against codling moth, *Cydia molesta* and *Ceratitis capitata.*

The use of **plastic cover** against fungal diseases or the introduction of bio-control agent is still at an experimental stage.

III. Best practices for reducing the use of pesticides on soft fruits

IPM is also developed on strawberries. The use of **warning models and traps** to inform growers and advisory services, combined with regular **monitoring of the plantation**, is essential to elaborate the best protection strategy. On strawberries, several diseases (*Botrytis, Colletotrichum*, powdery mildew) and pests (trips, mites, *Drosophila suzukii*) can be predicted like this. However, warning models for berry crops has not progressed at the same level as in the other fruit crops both in terms of production / development of new models or practical use of them.

Experiments to control trips and *Drosophila suzukii* by **beneficial insects** are going on, but work has to be done on the parasitoids, their biology, the way to multiply and to introduce them in the culture, and finally to preserve them to have the best efficiency against pests.

The **exclusion nets** against *Drosophila suzukii* is developed on raspberries and strawberries. The costs are high, but combined with some additional treatments it gives good results. Nevertheless, modified microclimate causes other problems, and the method needs further development.

Adjust spray schedules (by product choice and larger pre-harvest interval to lower the risk to have residues) could be more put into practice on soft fruits.

IV. Best practices to limit the risk of pesticides in the environment

Spray application techniques to decrease contamination

- multi-row tunnel sprayers : Tunnel sprayers are one of the most efficient spraying systems to avoid contamination of the environment due to spray drift. The spraying cloud is kept within the orchard and the risk of exposing non-target organisms, surface water, by-standers and residents is minimized. Sprayers are equipped with a collecting system which enables a very efficient use of the applied spray volume per hectare. However, the fact is that there is no common practice in most countries. There are some practical limitations as the slope and/or scale of the orchard.

- **"fixed" spraying systems :** different prototypes are under evaluation. The principle is to apply fungicides as near as possible to the infection. So even when the soil conditions are not good for tractors, the treatment can be done. Depending of the risks, it may limit the number of applications or not (ex. on apple scab). Furthermore, the idea is to reduce the exposure of the "usual" tractor driver by spraying without a tractor, and have fewer incidences on environment (drift, soil compaction).

- **tree injection :** it's another way to think to apply treatments, without a tractor, by direct injection in the trees. The idea is to treat only a few times. Experiments are going on. Technical aspects have to be resolved like the formulation of the injected products and the material to do the injection. The whole phytosanitary strategy has to be rethinked and the mode of action of the products is essential.

- **adjust the dose and volume to the tree surface & volume** : Applications (for orchards and strawberries treatments) have been developed to help fruit growers to calculate the correct dose and water volume. On experimental stage, work is done to reduce the doses and the water volume depending of the volume of the tree hedge (TRV = tree row volume). A method was established for optimising the adjustment of the dose-rate based on data from a tractor mounted with a scanning LiDAR system.

- **spray quality :** The aim is to elaborate and propose spray tests on movable wall to check the accuracy of the sprayer, but also to evaluate and certify drift reducing tools or techniques like the spray nozzle classification.

- **treat spray waste** : Spray waste is produced during filling of sprayers, cleaning of sprayers and after a spraying event. These remnants are a possible risk for point source contamination for soil, ground water and surface water. In the last few years a number of on-farm bioremediation systems have been developed, such as phytobacs and biofilters. Implementation is going on in a number of European countries. In France, in total 10 processes have been registered for fruit phytosanitary effluents. The technics are based on different modes of action : biological, ultra-filtration, dehydration, reverse osmosis, photocatalysis, flocculation, coagulation, adsorption on activated carbone. Demo-trials to validate treatment systems are carried out in other countries. In some regions, the objective is also to develop a common spray-waste treatment system for the growers in a "central" sprayer washing station.

Biodiversity

One of the pests where the **natural predation** is the most successful is the European spider mite in apple orchards.

Studies are going on **vegetation management** to increase beneficial insect's population in orchards (hedges, floral strips in the rows) and use of **semio-chemicals to attract** them.

To preserve earwigs, generalist predators, from phytosanitary treatments, a **management tool** has been established to choose products with less negative incidence on earwigs and know when to apply them to avoid the most sensible stages.

Further knowledge is needed to measure the incidence of chemical/alternative treatments on natural enemies and introduced beneficial insects.

More general, research is performed on the way to develop **ecological compensation zones** and **pest suppressive landscapes**.

<u>General remark to the content of the synthesis report</u> : the genetic aspects, plant resistant varieties, have not been taken into consideration in this synthesis report, although it might be one of the main factors to reduce the use of pesticides. This case should be discussed in WP 2 "Performance of new fruit varieties". It's the same for the questions on the best condition to harvest (optimized ripening degree) and on the best storage technology to store. Some elements will be treated in WP 4 "Postharvest handling and storage of fruit" to deliver a quality product to the consumers.

Summary for EIP dissemination

Project title: **EUFRUIT: European Fruit Network**

Keywords: pesticide residues, IPM, alternative techniques, Bio-control products

Summary:

The use of pesticides to insure a sustainable fruit production faces to retailer demands, who want fruits without residues, and to consumer concerns, who don't want to take a risk for their health by eating treated fruits. This situation causes to the production difficulties to manage pests and diseases, and to communicate with the whole food chain. More and more guidelines impose rules to the growers and only little information is given to the consumers to reassure them.

Furthermore, farmer's health is exposed to pesticides application, so as the various environmental compartments (soil, water, air, biodiversity) with an incidence of the sustainability of the agro-system.

On the other hand, production developed in the 90s IPM, integrated pest management, and research is done to find alternative solutions to the use of "chemical" products. Some techniques and strategies have been developed like the use of decision support system, mating disruption and other bio-control products, but also mechanical or physical ways like the enclosing nets against pests or hot water against diseases. Research focuses also on spray application improvements to optimize the treatments, adapt the doses and reduce the risk for environment.

The synthesis report of WP3 provides the state of the art on different European initiatives to reduce the use of pesticides. It describes what can be already used by the growers and what the consumer should know about plant protection.

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Geographical regions:

Country	Regions (NUTS 3 REGIONS)
Denmark	DK011 (Copenhagen), DK012 (Copenhagen and its environs), DK013 (North Zealand), DK014 (Bornholm), DK021 (East Zealand), DK022 (West- and South Zealand), DK031 (Funen), DK032 (South Jutland), DK041 (West Jutland), DK042 (East Jutland), DK050 (North Jutland).
Belgium	BE211 Arr. Antwerpen - BE212 Arr. Mechelen - BE213 Arr. Turnhout- BE221 Arr. Hasselt - BE222 Arr. Maaseik - BE223 Arr. Tongeren - BE231 Arr. Aalst - BE232 Arr. Dendermonde - BE233 Arr. Eeklo - BE234 Arr. Gent - BE235 Arr. Oudenaarde - BE236 Arr. Sint-Niklaas - BE241 Arr. Halle-Vilvoorde - BE242 Arr. Leuven - BE251 Arr. Brugge - BE252 Arr. Diksmuide - BE253 Arr. Ieper - BE254 Arr. Kortrijk - BE255 Arr. Oostende - BE256 Arr. Roeselare - BE257 Arr. Tielt - BE258 Arr. Veurne - BE310 Arr. Nivelles - BE331 Arr. Huy - BE332 Arr. Liège - BE334 Arr. Waremme - BE335 Verviers
France	FR211 Ardennes, FR241 Cher, FR244 Indre-et-Loire, FR246 Loiret, FR301 Nord, FR302 Pas-de-Calais, FR411 Meurthe-et-Moselle, FR412 Meuse, FR413 Moselle, FR414 Vosges, FR421 Bas-Rhin, FR422 Haut-Rhin, FR432 Jura, FR433 Haute-Saône, FR511 Loire-Atlantique, FR512 Maine-et-Loire, FR514 Sarthe, FR515 Vendée, FR532 Charente-Maritime, FR533 Deux-Sèvres, FR534 Vienne, FR611 Dordogne, FR614 Lot-et-Garonne, FR615 Pyrénées-Atlantiques, FR623 Haute-Garonne, FR628 Tarn-et-Garonne, FR631 Corrèze, FR632 Creuse, FR633 Haute-Vienne, FR712 Ardèche, FR713 Drôme, FR714 Isère, FR716 Rhône, FR717 Savoie, FR718 Haute-Savoie, FR721 Allier, FR722 Cantal, FR723 Haute-Loire, FR811 Aude, FR812 Gard, FR813 Hérault, FR815 Pyrénées-Orientales, FR821 Alpes-de-Haute-Provence, FR822 Hautes-Alpes, FR823 Alpes-Maritimes, FR824 Bouches-du-Rhône, FR825 Var, FR826 Vaucluse, FR831 Corse-du-Sud, FR832 Haute-Corse
Germany	DE600 Hamburg; DE932 Cuxhaven; DE933 Harburg; DE939 Stade; DEF09 Pinneberg
Netherlands	NL230 Flevoland; NL310 Utrecht; NL321 Kop van Noord-Holland; NL338 Oost-Zuid-Holland; NL341 Zeeuwsch-Vlaanderen; NL342 Overig Zeeland; NL411 West-Noord-Brabant; NL412 Midden-Noord-Brabant; NL422 Midden-Limburg; NL423 Zuid-Limburg.
Spain	ES 512 Girona, ES513 Lleida
Switzerland	
Italy	ITH10 Bozen-Bolzano, ITH54 Modena, ITH55 Ferrara, ITH57 Ravenna, ITH58 Forlì-Cesena, ITH59 Rimini, ITD20 Trentino-Alto Adige
Romania	RO111 Bihor, RO112 Bistrița-Năsăud, RO113 Cluj, RO114 Maramureș, RO115 Satu Mare, RO116 Sălaj, RO121 Alba, RO122 Brașov, RO123 Covasna, RO124 Harghita, RO125 Mureș, RO126 Sibiu, RO211 Bacău, RO212 Botoșani, RO213 Iași, RO214 Neamț, RO215 Suceava, RO216 Vaslui, RO221 Brăila, RO222 Buzău, RO223 Constanța, RO224 Galați, RO225 Tulcea, RO226 Vrancea, RO311 Argeș, RO312 Călărași, RO313 Dâmbovița, RO314 Giurgiu, RO315

	Ialomița, RO316 Prahova, RO317 Telorman, RO321 București, RO322 Ilfov, RO411 Dolj, RO412 Gorj, RO413 Mehedinți, RO414 Olt, RO415 Vâlcea, RO421 Arad, RO422 Caraș-Severin, RO423 Hunedoara, RO424 Timiș
Lithuania	LT001 Alytaus apskritis, LT002 Kauno apskritis, LT003 Klaipėdos apskritis, LT004 Marijampolės apskritis, LT005 Panevėžio apskritis, LT006 Šiaulių apskritis, LT007 Tauragės apskritis, LT008 Telšių apskritis, LT009 Utenos apskritis, LT00A Vilniaus apskritis
UK	UKG11 Herefordshire, UKG12, Worcestershire, UKH12 Cambridgeshire, UKH16 North and West Norfolk, UKH17 Breckland and South Norfolk, UKJ22 East Sussex, UKJ35 South Hampshire, UKJ36 Central Hampshire, UKJ37 North Hamphshire, UKJ41 Medway, UKJ43 Kent Thames Gateway, UKJ44 East Kent, UKJ45 Mid Kent, UKJ46 West Kent
Sweden	SE224 Skåne län, SE123 Östergötlands län, SE221 Blekinge län, SE213 Kalmar, SE231 Halland, SE232 Västra Götaland

Project web page: www.eufrin.org

Annex: Scanning reports

List of the scanning reports : 18 documents (PDF file joint)

- Aarhus University (DK)
- Pcfruit (pome fruit & strawberries) (BE)
- Ctifl (apples & stone fruits) (F)
- OVA Jork (DE)
- St DLO Wageningen (NL)
- IRTA (ES)
- Agroscope (Pome fruit & stone fruit)
- Laimburg (IT)
- USAMV (RO)
- LRCAF (LT)
- UoG (UK)
- Kob-Bavendorf (DE)
- UNIBO (IT)
- Fondazione Edmund Mach (IT)
- Swedish Board of Agriculture (