IMPROVING INPUTS FOR ORGANIC FARMING

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1. Executive summary

Natural substances are an important component of organic plant protection strategies, mainly in perennial crops. Only a small number of products and substances are authorised for plant protection in organic production. Organic farming constantly evolves, and new inputs are proposed to replace contentious inputs traditionally used or to tackle yet unsolved production obstacles, including invasive pests and diseases or the consequences of climate change.

The RELACS project aims at developing alternative products and tools to reduce the use of contentious inputs in plant protection, namely copper and mineral oils. Three far-advanced products resulting from previous research projects and a product from outside RELACS have been tested as alternatives to copper. For mineral oil alternatives, RELACS has investigated two products and a vibration disruption mating technique.

The results of RELACS on these alternatives were presented to relevant stakeholders of the organic sector and to EU policymakers, in order to assess their acceptability of the alternatives and to identify under which conditions they could be adopted. This multi-actor approach and fact-based dialogue allowed to develop a "European roadmap to reduce contentious plant protection products in organic farming systems", with the aim to propose fair, reliable and implementable rules to achieve an identified realistic reduction pathway of copper and mineral oil.

For copper, the results of the RELACS project allow to envisage a future in which more solutions are available for the gradual reduction of copper use. The four copper alternatives developed under RELACS vary in terms of efficacy depending on the crop/disease combination, but none of the alternatives is as effective as copper under high disease pressure or highly conducive weather conditions. It is clear that a range of alternatives will be necessary to cover the broad spectrum of copper uses. At this stage, the evaluated alternatives are most likely best integrated into a copper minimization strategy whereas a full replacement is considered not feasible. In low-risk conditions, however, complete replacement of copper could be an option.

As for mineral oils, it is not possible to envisage a phasing out in organic farming in the current state of knowledge, but the alternatives developed by RELACS show a good potential to reduce their use. In particular, the use of vibration signals in synergy with the two alternative products seems to be very promising.

The RELACS project shows that reduction pathways for copper and mineral oil are possible in a near future, but their achievement will require a strong policy support in several fields. The major challenge identified is to adapt the EU registration process for active substances to plant extracts to facilitate their access to the market and availability for farmers. Additionally, policy support for continuous research and market development is needed. Finally, the use of the alternatives will be demanding for farmers due to higher product costs and the additional knowledge needed for their successful use. Therefore, incentives will have to be introduced to encourage farmers to engage in further reduction of copper and mineral oils.

Policy support for the transfer of the alternatives developed by RELACS to the EU market will also contribute to the Farm to Fork Strategy's target of reducing the overall use and risk of chemical pesticides by 50% by 2030.

It is important to note that reducing the use of contentious inputs in organic farming is not about replacing one input with another, but about improving the whole production system by implementing preventive measures and enhancing biodiversity. The alternatives developed by RELACS offer good prospects in the reduction of contentious inputs, which should be complemented by further research on preventive measures and biodiversity enhancement to fully optimise the system approach of organic farming to minimise the use of external inputs.

2. Introduction

One of the main principles of organic production is the appropriate design and management of biological processes and natural resources which are internal to the agroecosystem, with the aim of making them resilient. Healthy agroecosystems enable farms to depend as little as possible on external inputs.

Plant health in organic farming is mainly based on preventive and indirect management measures. Organic farmers can use biocontrol or natural substances when diseases and/or pests occur at unsustainable levels. The intelligent combination of these measures provides an effective plant health strategy while maintaining the overall resilience of the system.

Organic farmers limit themselves to using substances that already exist in nature, as an active precautionary measure. Therefore, only plant protection products based on natural substances are allowed in organic production, provided they are not harmful to the environment, humans and animals and respect the traditions of the sector and/or the expectations by organic farmers and consumers.

Natural substances are an important component of organic plant protection strategies, mainly in perennial crops. Only a small number of products and substances are authorised for plant protection in organic production. They are listed in Annex I of the Regulation (EU) No 2021/1165[1]. Organic farming constantly evolves, and new inputs are proposed to replace contentious inputs traditionally used or to tackle yet unsolved production obstacles as well as the consequences of climate change.

Apart from the potential negative impact on the environment, the use of contentious inputs can also be publicly criticised and presents a risk for the further development of the organic sector. Reducing controversial practices is thus a priority strategy to safeguard the achievements and investments of the sector and to ensure its future development, especially with regards to the Farm to Fork target of 25% of EU agricultural land under organic agriculture by 2030.

The RELACS project aims at developing alternative products and tools to reduce the use of contentious inputs in plant protection, namely copper and mineral oils.

This roadmap presents the steps to reach this goal.

3. Methods

RELACS is broken down into 6 research and development work packages (WPs1-6), in which scientists and farmers working closely together with industry partners have developed, explored and adapted innovative solutions and strategies to reduce the use of copper (WP1), mineral oil (WP2), contentious fertilisers and manures (WP3), anthelmintics (WP4), antibiotics (WP5) and synthetic vitamins (WP6); one work package dedicated to the science-practice dialogue to support the development of relevant EU policies (WP7); one for outreach and technology transfer (WP8); and one for consortium and project management (WP9). All WPs are strongly linked to and interacting with WP7, leading the development of three European roadmaps for the reduction of contentious inputs in organic production:

i. European roadmap for the reduction of contentious plant protection products: copper and mineral oil
ii. European roadmap for the reduction of contentious fertilisers and manures in plant nutrition
iii. European roadmap for the reduction of contentious inputs used in livestock production: antibiotics, anthelmintics and vitamins

The aim of the RELACS European roadmaps is to propose fair, reliable and implementable rules to achieve an identified realistic reduction pathway for each of these six priority contentious inputs.

The roadmaps have been developed through a multi-actor approach and a fact-based dialogue. As a first step, workshops were organised at national level to present and discuss the alternatives developed within RELACS to relevant stakeholders of the organic sector. Then, the outcomes of the national workshops were presented and

[1] Commission Implementing Regulation (EU) 2021/1165 of 15 July 2021 authorising certain products and substances for use in organic production and establishing their lists

discussed during a European workshop. All the outcomes of these workshops provide the basis for the preparation of the three European roadmaps.

3.1 National workshops

21 national workshops were organised in 9 EU Member States (France, Italy, Spain, Bulgaria, Hungary, Germany, Denmark, Estonia, Belgium) and the United Kingdom, gathering practitioners, advisors, national authorities and scientists (see Figure 3-1 and Annex I), to discuss the pros and cons of alternative tools and techniques developed by RELACS, explore the current acceptance level as well as identify necessary adaptations of current legislation to enable the uptake of these alternatives.

Each workshop focused on one contentious input and its alternatives. Depending on the national context, one or more workshops were organised (see Table 3-1).

The workshops to discuss alternatives to the use of synthetic vitamins could not be organised, because of difficulties in gathering the relevant participants. Unlike all the other workshops of which the main stakeholders are the farmers, the relevant stakeholders to discuss alternatives to synthetic vitamins are the feed mills, which supply both the conventional and organic sectors. Too few of these actors showed interest in participating in a RELACS workshop. This could be explained by the fact that the national networks of feed mills are less developed than the organic farmers' networks, and the fact that they are operating in a competitive market which makes it difficult to create sufficient confidence.

Table 3-1 Overview of national workshops organised by RELACS

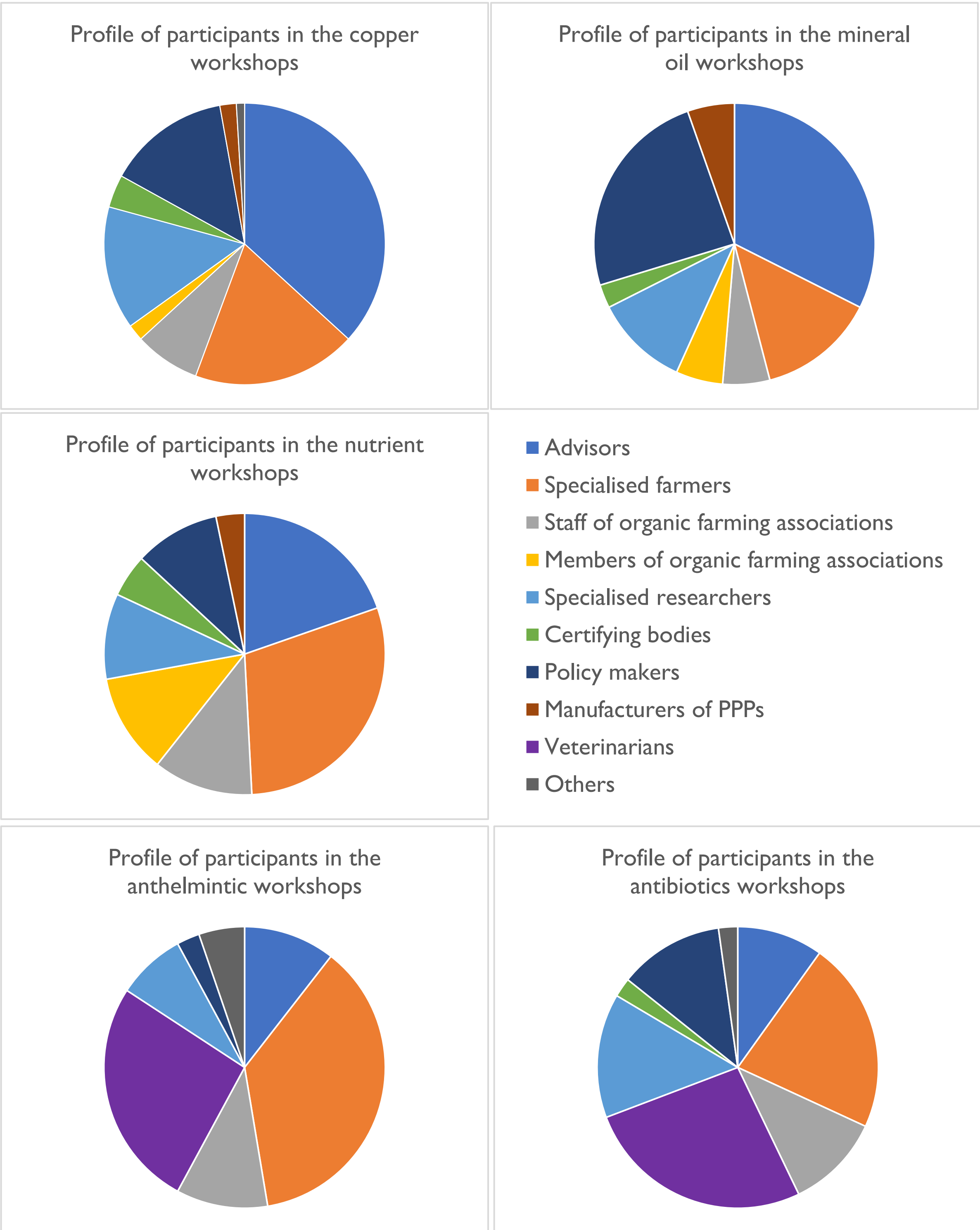
	Copper	**Mineral Oils**	**Nutrients**	**Anthelmintics**	**Antibiotics**	**Vitamins**
France					2020 & 2021	
UK	Aug. 2021			June 2021	June 2021	
Hungary	Sept. 2021		Sept. 2021			
Spain	June 2021	June 2021			July 2021	
Italy	May 2021	May 2021	May 2021			
Germany	Sept. 2021		April 2021	April 2021	April 2021	
Estonia			Sept. 2021		Sept. 2021	
Belgium	July 2021					
Denmark			Sept. 2021			
Bulgaria	June 2021					
TOTAL	**7**	**2**	**5**	**2**	**5**	**/**

Technical dossiers on each alternative input or method were prepared by the research and technology development (R&D) work packages (WPs 1-6) and shared with the participants before the workshop. Each dossier provides basic information on the alternative proposed: technical, chemical and physical properties, specification of use, side effects, regulatory status, price and compliance with organic principles.

During the workshops, participants were invited to give their views on the acceptability of the alternatives presented regarding their efficacy, environmental impact, cost/benefit and practical obstacles to their uptake. They were also invited to identify knowledge and advisory needs to enable the uptake of the alternatives. Optionally, participants were also asked to identify regulatory and market aspects that might influence the adoption of the alternatives (registration, regulatory obstacles, scalability, supply chain).

Based on this assessment, the participants had to conclude for each alternative whether it could be accepted to reduce the use of the contentious inputs, and under which conditions. Participants were also asked to propose national recommendations and actions to reduce contentious inputs, elucidate bottlenecks and propose timelines for implementation. The outcomes of the national workshops are compiled in input-specific national roadmaps.

Figure 3-1 Overview of the profiles of the participants in the national workshops



3.2 European workshop

A European workshop took place the 2nd of December 2021, with the aim to share the conclusions of the national roadmaps and to discuss the actions needed at EU level to help reduce the use of contentious inputs and, more generally, to design fair, reliable and implementable EU rules on the use of inputs in organic production. The workshop was attended by about 50 people. Participants were mainly RELACS and Organic-PLUS partners; a few participants were from the European Commission or industry.

A summary of the outcomes of the national workshops was presented to the participants, focusing on the level of acceptance of the alternatives by farmers and the main obstacles to their adoption that were identified. Then, the participants were divided into three working groups corresponding to the topics of the three RELACS European roadmaps (plant protection, nutrients, livestock). Based on the results of the national workshops, they brainstormed on potential solutions at EU level to facilitate the adoption of the alternatives developed by RELACS and considered acceptable by farmers.

The aim of the three RELACS European roadmaps – on the reduction of contentious plant protection products, nutrients, and inputs used in livestock production – is to provide recommendations for the reduction of contentious inputs in organic agriculture based on science and facts and in close discussion with relevant stakeholders through the RELACS national and European workshops.

4. Overview of the EU procedure for the authorisation of plant protection products in organic farming

The Organic Regulation (EU) 2018/848[2] defines the principles and practices of EU organic agriculture, including the rules on the use of inputs. It establishes that inputs in organic agriculture are limited to "natural or naturally-derived substances". This means that plant protection products composed of synthetic active substances are not authorised in organic production (except synthetic active substances chemically identical to natural substances). Additionally, they must be compatible with the objectives and principles of organic production to be authorised. Finally, only products and substances that have been previously authorised in the relevant EU's horizontal legislations can be used in organic production.

Therefore, the authorisation of any new non-living input for organic production must follow two regulatory steps: first, the input has to be registered in the corresponding EU's horizontal legislation, then it has to be added to the annexes of Commission Implementing Regulation (EU) 2021/1165 of 15 July 2021 authorising certain products and substances for use in organic production and establishing their lists.

4.1 Authorisation in the EU horizontal legislation on pesticides

This step is mandatory for any input, regardless of whether it is used in conventional or organic farming. Regulation (EC) 1107/2009[3] lays down the rules and procedure for the approval of active substances and the placing on the market of plant protection products. Active substances are approved at EU level, while plant protection products are authorised at Member State level.

4.1.1 Approval of active substance

The producer of an active substance who wants to apply for EU approval must submit a dossier to a designated Rapporteur Member State (RMS), containing scientific information and studies complying with the data requirements set out in Regulation EU 283/2013: identity of the active substance, physical and chemical properties, toxicological and ecotoxicological profile, environmental fate and behaviour, residues and a range of further information. The RMS carries out an initial risk assessment and prepares a draft assessment report which will be peer-reviewed by

[2] Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007
[3]

the European Food Safety Authority (EFSA) in cooperation with all Member States. Then EFSA issues its conclusions on whether the active substance may be expected to meet the approval criteria established in Regulation 1107/2009.

Based on EFSA's conclusions, the assessment of the RMS, and other legitimate factors, the Commission presents a draft Regulation for approval or non-approval of the active substance to the Standing Committee on Plants, Animals, Food and Feed (ScoPAFF), which is composed by national experts representing EU Member States. The ScoPAFF decides by qualified majority to approve or reject the Commission's proposal. The result of the vote is binding for the Commission. If there is no qualified majority in favour or against the Commission's proposal, a new vote is organised in Appeal Committee, following the same rules. If there is still no qualified majority in Appeal Committee, the Commission can decide to adopt or reject its proposal. All approved active substances are listed in Implementing Regulation (EU) No 540/2011[4].

Completing the evaluation for first approval of an active substance should take between 2.5 to 3.5 years (according to the timelines set out in Regulation (EC) No 1107/2009). However, according to the Commission, **the procedure on average takes 3 years and 7 months**[5]. This figure is a general average which includes applications for both synthetic and natural substances. In practice the procedure for natural substances is even longer.

4.1.2 Authorisation of plant protection products

Regulation (EC) 1107/2009 establishes a zonal system for the authorisation of plant protection products, in which the EU is divided into three zones – North, Central and South – grouping Member States with comparable agricultural conditions. Mutual recognition is a key element of this system.

An applicant for authorisation of a plant protection product must apply in each Member State where the product is intended to be placed on the market. The application must specify the list of intended uses in each zone and the Member States where the applicants has made or intends to make an application. A zonal Rapporteur Member State is selected for each zone where the plant protection product shall be authorised. The zonal system aims to have only one Member State per zone concerned assessing the application. If that Member State decides to grant an authorisation for that plant protection product, the applicant can then apply for "mutual recognition" in another Member State in the same zone to have the product authorised in that Member State. In some cases, the EU is considered as a single zone, and the authorisation of a plant protection product in one Member State can therefore be used for "mutual recognition" in all Member States (e.g. for greenhouse uses).

4.1.3 Discussion on the authorisation process for natural substances

Regulation (EC) 1107/2009 laying down the rules for the authorisation of active substances and plant protection products was designed for synthetic substances and is not adapted to natural substances in many aspects. This creates technical difficulties and may even lead to non-authorisation of a natural active substance due to technical constraints. For instance, it may be difficult to identify and characterize all individual compounds of a botanical active substance containing a hundred different ones.

The European Commission has proposed some solutions to facilitate the registration process of natural substances. There are guidance documents for several categories of natural substances, including microorganisms, semiochemicals and botanicals (plant extracts), which contribute to a more appropriate evaluation of these substances. Yet improvements and additional guidance documents are still needed.

Regulation (EC) 1107/2009 recently introduced the 'basic substances' category. It describes substances useful in plant protection but not predominantly used for this. For instance, vinegar, stinging nettle extract, or sucrose are registered as basic substances. The registration process is supposed to be less demanding, less expensive and faster

[4] Commission Implementing Regulation (EU) No 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances
[5] Approval of active substance (europa.eu): https://ec.europa.eu/food/plants/pesticides/approval-active-substances_en

than for standard PPPs. However, the practical implementation of this process is challenging. Due to a lack of data, many substances are authorised for only a few uses needed in organic farming.

4.2 Authorisation in Organic Regulation

Annex I of the Implementing Regulation (EU) 2021/1165 establishes the list of active substances that may be contained in plant protection products used in organic production, provided that these plant protection products are authorised pursuant to Regulation (EC) 1107/2009. To be included in this list, active substances have to go through another evaluation process to ensure that they comply with the principles of organic farming.

It is the Commission that decides on the addition of an active substance to Annex I, more precisely the "Organics" Unit of DG AGRI. Member States can submit to the Commission any request to do so. Before taking its decision, the Commission receives advice from the expert group for technical advice on organic production (EGTOP), which is a permanent group of the Commission composed of independent scientists and other experts from EU countries with competences related to organic production.

The EGTOP assists the Commission by assessing for each substance the compliance of the following criteria with the objectives and principles of organic production:

- Necessity for intended use and known alternatives
- Origin of raw material and manufacturing process
- Environmental issues, use of resources, recycling
- Animal welfare issues
- Human health issues
- Food quality and authenticity
- Social, economic, and ethical concerns

Based on this technical evaluation, the EGTOP also provides non-binding recommendations on the authorisation of the substances for organic production. There is no pre-established logic for weighting the criteria against one another. The expert group follows a holistic approach and decides on a case-by-case basis.

The Commission generally follows the EGTOP's opinion. Any Commission's proposal concerning the authorisation of a new active substance for organic production (meaning its inclusion in Annex I) is submitted for approval by the Committee on Organic Production, composed of representatives of EU Member States. The Commission's proposal may specify more restrictive conditions for the use of a given substance in organic production than those laid down in Implementing Regulation (EU) 540/2011.

5. Reduction of copper

5.1 Problems associated with the use of copper

Copper is an essential trace element which is used in both conventional and organic plant protection products against bacterial and fungal diseases but also as a foliar fertiliser as well as a supplement in animal nutrition.

In plant protection, copper is active against an extraordinary range of pathogens (more than 100) including bacteria, oomycetes, ascomycetes and basidiomycetes. Several crop diseases treated by copper such as downy mildew of grape, apple scab and late blight of potato are of world-wide importance, but copper is also a useful tool against minor diseases and, against diseases in minor crops such as vegetables or specialty fruits. After more than 100 years of use, so far no resistance of fungal/oomycete pathogens to copper have been reported, and only few resistance for bacterial pathogens (Lamichhane et al., 2018). Furthermore, copper presents excellent rain fastness, low phytotoxicity potential and good activity at low temperatures. Today, copper is the only effective fungicide authorised for some uses in organic farming. Due to its unique features, copper is also an important tool in conventional agriculture and integrated pest management.

Currently, copper is approved in the EU as an active substance in plant protection products for more than 50 different diseases in viticulture, horticulture, hops, market garden and arable crops. However, copper is an element of scarce mobility in the soil, and repeated foliar applications lead to accumulation in the soil (Ballabio et al., 2018), which can negatively affect soil microorganisms and fertility (La Torre et al., 2018; Lamichhane et al., 2018). Therefore, the use of copper-based fungicides has been successively restricted in the EU over the past years, and copper is listed in Europe as a candidate for substitution[6]. Since 1st January 2019, the maximum total amount of copper is limited to 28kg per hectare over a period of 7 years as established by Regulation (EU) 2018/1981[7]. Member States are allowed to set a maximum annual application rate not exceeding 4 kg/ha of copper. In a range of countries, organic farmer organisations limit copper use beyond the legal requirements. Several Member States even decided not to register any copper-based plant protection products at national level (including the Netherlands and Denmark) (Tamm et al., 2022).

As mentioned earlier, copper has been used by European farmers for more than 100 years, sometimes in high amounts. It is worth to note that the organic sector was the first to impose itself limits to copper use per hectare: in 2002, a maximum of 8 kg per hectare and year was allowed which was reduced in 2006 to 6 kg/ha/year (with a smoothing mechanism over 5 years each time)[8]. No limit to copper use was imposed to conventional farmers before 2019. In line with its objective to minimise the dependency of organic farming on external inputs, the organic sector has been active for decades in the design and implementation of strategies to minimise the use of copper.

The protection of biodiversity and the soil are key topics for agriculture, and it is likely that plant protection products such as copper will probably be handled even more restrictively in the coming years. However, there is a common understanding that with the current technology and without innovation, no substantial further reduction of copper is possible in the main crops it is used for, particularly in view of the increasing difficulties due to climate change and invasive diseases (Tamm et al., 2022). Currently, none of the commercially available alternatives has a similar range of use as copper, and it is unlikely that an alternative product with the same properties as copper will ever be developed.

Therefore, in addition to thorough minimisation strategies, potential alternatives to copper would rather be a set of several natural substances covering the entire range of effects of copper. It is also important that the use of these substances is environmentally friendly. The development of such alternatives should be thought in a system approach, consisting of ‘smart’ combinations of alternative products (if legally available), robust varieties and agronomic practices.

The RELACS project aimed to develop new products and strategies to minimise use of copper in organic plant production. Four pilot products which are far advanced and have a proven activity under field/greenhouse conditions against the main diseases in grapevine, apple, cucumber and tomato have been further developed for four years.

5.2 Tools and techniques developed in RELACS or outside

In RELACS, three far-advanced alternative products resulting from previous research projects have been taken forward in order to develop copper alternatives: liquorice extract, larch extract larixyne, and one rare sugar. Additionally, a fatty acid product from outside RELACS has been tested in apple: NEU1143 F.

The crops and diseases addressed in RELACS for copper reduction are:

- Grape/downy mildew (*Plasmopara viticola*)
- Apple/scab (*Venturia inaequalis*)
- Cucumber/downy mildew in greenhouse (*Pseudoperonspora cubensis*)

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[6] Part E of the Annex to Commission Implementing Regulation (EU) No 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances

[7] Commission Implementing Regulation (EU) 2018/1981 of 13 December 2018 renewing the approval of the active substances copper compounds, as candidates for substitution, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market, and amending the Annex to Commission Implementing Regulation (EU) No 540/2011.

[8] Commission Regulation (EC) No 473/2002 of 15 March 2002 amending Annexes I, II and VI to Council Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs, and laying down detailed rules as regards the transmission of information on the use of copper compounds.

- Tomato/late blight in greenhouse (*Phytophthora infestans*)
- Diseases in minor-use specialty crops (e.g. oil bearing roses)

Trials were performed under different field and climate conditions in several countries distributed over Europe. The aim was to develop integrated strategies for copper reduction, which include agronomic preventive approaches.

The main characteristics of the alternative products developed in and outside RELACS are presented in the following sections.

5.2.1 Liquorice

Description	Technical grade extract of *Glycyrrhiza glabra* leaves
Type of use	Liquorice extract may be used as a fungicide against plant pathogens in grape vine.
Mode of action	The bioactive compounds in liquorice work as contact fungicide with protective activity on foliar surfaces. The compounds directly kill the target fungus. They inhibit various life stages of the fungus: mycelia growth, zoospore release and germination and sporangia germination thereby preventing the penetration of host tissue.
Efficacy	• Very good efficacy under low to medium and severe disease pressure situations • Higher efficacy on berry protection than copper products
Side effects	• No negative impact documented on crops • No negative effect as far as known (full evaluation pending) on animals, human health, environment, and food quality
Historic of use & regulatory status	Liquorice extracts have been used extensively in foods, tobacco, and cosmetics sectors. The use of the aboveground material has no historic use and is described as waste material. Liquorice extract needs registration under Regulation (EU) 1107/2009 and inclusion in Annex I of the Organic Regulation.
Origin of raw material & production method	Waste product of commercial liquorice production sites from former Soviet Union, Europe, the Middle East (location of global processing industries e.g. Pharma, Food, Tabaco). To avoid overharvesting of wild liquorice cooperation's of liquorice cultivation has been successfully undertaken. Liquorice leave extract is produced with 'green solvents' (e.g. ethanol)
Scalability	Cultivation of the desired variety of liquorice has been implemented to provide a sufficient amount of raw material with other liquorice processing industries and raw material suppliers already on the market. The extraction process has already been developed in a pilot scale of up to 1 tonne of liquorice leaves. Implementation of a large-scale process can therefore easily be achieved.
Costs	Likely to be more expensive than copper

5.2.2 Larixyne

Description	Technical grade extract of larch bark and wood
Type of use	Larch extract may be used as a fungicide against downy mildews in grapevine. A range of other pathogens and minor uses is currently under evaluation.
Mode of action	Contact fungicide mainly (no systemic translocation in plant or curative activity), induction of resistance is possible.
Efficacy	• Has good – very good efficacy under low to medium severe weather conditions

	• Larixyne is less persistent on leaves than copper due to degradation and washing off by rain fall
Side effects	• Excessive use may lead to phytotoxicity on leaves and grapes • No negative effect as far as known (full evaluation pending) on animals, human health, environment, and food quality
Historic of use & regulatory status	No historic of use as plant protection product Larch extract needs registration under Regulation (EU) 1107/2009 then inclusion in Annex I of the Organic Regulation (EU) 2021/1165.
Origin of raw material & production method	Larch occurs naturally in Europe in France, Germany, Italy, Switzerland and Austria. Larch extract will be extracted from side products such as bark and saw dust. The technical grade is extracted by green technologies.
Scalability	Production is scalable, though the quantities depend on availability of by-products from larch wood industry.
Costs	Likely to be more expensive than copper

5.2.3 Rare sugar

Description	This Rare Sugar is a monosaccharide. It is a carbohydrate, a ketohexose, an epimer of D-fructose inverted at C-4. It takes the form of a white, anhydrous crystalline solid.
Type of use	The Rare Sugar can be used as fungicide against downy and powdery mildew on tomato, grapevine, apple, cucumber.
Mode of action	The Rare Sugar reduces the growth of phytopathogenic fungi by interaction in the sugar metabolism. It causes the reduction of glycolysis and mannose metabolism in multiple developmental stages of the pathogen including the formation of conidiophores, conidia, and oospores, and thus induces disease tolerance, and reduces the development of symptoms.
Efficacy	Direct effects on different stages of pathogen development.
Side effects	No negative effect as far as known on animals, human health, environment, and food quality. The Rare Sugar has been declared as safe by the Food and Drug Administration (FDA) in the United States and the World Health Organization (WHO) in 2001.
Historic of use & regulatory status	The Rare Sugar is used as a bulk sweetener, and like other sugars (sucrose, glucose, fructose) it is also used as a humectant, texturizer and stabilizer. It is also useful in formulating dietetic foods with a low glycaemic index. There is no historic use as plant protection product. The Rare Sugar needs registration under Regulation (EU) 1107/2009 then inclusion in Annex I of the Organic Regulation (EU) 2021/1165.
Origin of raw material & production method	The Rare Sugar is derived from a natural source that is available in large quantities, by simple chemical or enzymatic processes.
Scalability	The production process can easily be scaled up.

Costs	The price range of the product is not yet determined but is likely to be more expensive than copper.

5.2.4 NEU1143 F

Description	Iron salt of pelargonic acid
Type of use	Iron salt of pelargonic acid will be used as a fungicide against foliar plant pathogens, especially apple scab and *Monilinia*. A range of minor uses is currently under evaluation.
Mode of action	It is described as a contact fungicide with two modes of action: inhibition of spore germination and inhibition of mycelial growth. The fatty acid damages the cell membrane and active iron ions disturb the intracellular metabolism. It is also claimed that inherent plant defense activity is triggered (Christoph Stumm, Institut für Organischen Landbau, Katzenburgweg 3, 53115 Bonn, 0228-732038; Prokop et al, 2016)).
Efficacy	Iron salt of pelargonic acid can be used as stand-alone replacement of copper under appropriate pedo-climatic conditions. As an alternative to copper in apple, it will most likely be used to replace some copper treatments early but also later in the season and thus reduce overall use of copper during the season or to increase yield stability in addition to standard copper use.
Side effects	On crops: Fruit russeting on apple is possible on sensitive varieties after several applications; induction of resistance is possible. No negative effect as far as known (full evaluation pending) on animals, human health, environment, and food quality.
Historic of use & regulatory status	Pelargonic acid is used (in general agriculture) as herbicide and as a blossom thinner for apple and pear trees. It is also used as a food additive. The iron salt of pelargonic acid is a newly developed plant protection product and therefore has no traditional use in organic agriculture. Iron salt of pelargonic acid needs registration under Regulation (EU) 1107/2009 then inclusion in Annex I of the Organic Regulation (EU) 2021/1165.
Origin of raw material & production method	Pelargonic acid (in the form of esters) occurs naturally in various plant species, particularly in the plant family Geraniaceae. It is named after the genus Pelargonium. Iron salt of pelargonic acid may be obtained from plants or synthetically manufactured.
Scalability	Pelargonic acid is available in large quantities. The synthetic production of iron salt of pelargonic acid will be more easily replicated on larger scale.
Costs	Iron salt of pelargonic acid is significantly more expensive than copper.

5.3 Farmers' acceptance level of the alternatives proposed by RELACS

The acceptance level of farmers for the alternatives developed in or outside RELACS to reduce the use of copper was assessed during the RELACS national workshops (see part 2.) In addition to the four alternative plant protection products developed by RELACS or industrial partners, farmers were also asked about their acceptability of resistant varieties for apple and grape vine.

5.3.1 Alternative plant protection products

The outcomes of the workshops show that farmers are highly interested in alternatives to copper, though they stress that plant protection products are only one component of the systemic approach to plant health implemented in organic agriculture. According to their general feedback, the development of alternative products is part of the solution to reduce copper use, but it is also important to develop the other components of the strategy such as resistant varieties, plant cultivation methods and lower application rates.

The feedback from the farmers on each alternative plant protection product proposed by RELACS is quite similar. This is due to the fact that studies were still ongoing, as well as data collection related to environmental impacts, practicality of use and costs. Therefore, there was not enough data to assess each alternative in detail. However, this is not really a problem because at this development stage of the products, it is mainly the possibility of reducing copper use with these alternatives and not their specific characteristics that interests farmers. **The efficacy may vary between alternatives, but as long as products can reduce copper use without negative environmental impact or excessive cost, farmers are interested and willing to accept the alternatives**. Nevertheless, they believe that further research is needed to fully assess the efficacy, environmental impact and adverse effects of the proposed alternatives, and from a more practical point of view, how they can be used with other plant protection products and as part of an integrated plant health strategy.

In conclusion, farmers estimate that, based on current knowledge**, there is no reason for not accepting the four alternative products presented**. The data provided through further research should allow them to confirm this preliminary conclusion. They also agreed that none of the alternative products presented can completely replace copper in terms of efficacy. A range of several alternative products seems to be the most feasible and acceptable scenario for copper reduction on medium term.

In addition, farmers raised several points of attention:

- Efficacy under rainy conditions: this aspect will be an important criterion for the adoption of alternatives to copper.
- Resistance management: farmers emphasize that copper reduction strategies that include alternative plant protection products must prevent the appearance and development of pest and disease resistance to these products.
- Costs: the cost of the alternatives is a sensitive topic for farmers. All the alternative products will be more expensive than copper, which is a very cheap product. Farmers are willing to pay slightly higher prices for alternative products if solid evidence on efficacy and environmental safety is provided. Since all the products presented are less effective than copper under high disease pressure conditions, prices that are too high will not be accepted.
- Social acceptability of the alternatives: some farmers expressed doubts about the social acceptability of certain alternatives if they are composed of nature-identical substances that are synthetically manufactured. The synthetic manufacture of nature-identical substances may be an option to reduce production costs and/or achieve sufficient production capacity. Even if this is allowed under the organic regulation, farmers are concerned that consumers will feel cheated if they use such products. The same concerns are raised for alternatives that at the same time are authorised as herbicides in conventional agriculture (albeit in much higher dosages), because herbicides are prohibited in organic agriculture. Therefore, some farmers will be more reluctant to turn to such alternatives.

5.3.2 Resistant varieties

Farmers unanimously agree that resistant varieties are a very important pillar of any copper reduction strategy. The amount of copper that can be reduced depends on the specific variety, the region, the year and the type of production: fruit (apple/pear) or wine.

Resistant varieties are commonly used in apple orchards, but the current resistant varieties rely mainly on monogenetic resistance that is already broken. Therefore, the potential for copper reduction is decreasing at the moment. In wine production, the use of resistant varieties is established as a niche production only. Reasons include lack of consumer acceptance and difficulties to find its place on the market, as consumers are attached to traditional varieties with well-defined organoleptic characteristics. Furthermore, planting of new cultivars has been prohibited in important countries especially in 'designation of origin' regions (see below). Consumer preferences and market trends are a central factor in the acceptance of resistant varieties by farmers. If the varieties are not excellent in quality and productive, they will not be adopted, even if they are resistant. Apple growers are more interested in new resistant varieties than wine growers, as consumers and markets have already widely adopted resistant apple varieties (Ariane, Topaz), whereas this is not yet the case for wine. But even if fruit growers are willing to adopt new resistant varieties, the long-term investment this represents for long-lived trees (e.g. for pear trees between 40 and 70 years) is substantial. Furthermore, the replacement of perennial crops on a large scale is a long-term project.

5.4 Obstacles to the adoption of the alternatives

Whether in terms of scientific results or acceptability by farmers, the alternatives developed by RELACS show a good potential to be integrated into future copper reduction strategies. However, several obstacles to the adoption of the alternatives were identified.

Most of the alternatives to copper developed by RELACS are plant extracts, and their **registration constitutes the main barrier to their adoption**. **Access to the EU market and ultimately to farmers is challenging for these substances**.

The EU registration process established by Regulation 1107/2009 is long, costly, and unpredictable for plant protection products based on plant extracts, which usually dissuades companies from applying for authorisation. Indeed, a botanical active substance may contain hundreds of different compounds which may vary depending on its geographical origin. Therefore, it is difficult to identify and characterize all individual compounds, while this is usually required to carry out the risk assessment. Registration (preparation of a dossier and the assessment process) takes several years; therefore, the alternatives evaluated in RELACS may only become available in several years, provided that a company decides to apply and the assessment of the application runs smoothly (which is usually not the case, especially for botanical products).

The same logic applies for the admission of new resistant varieties. However, the main issue here is the lack of availability of suitable cultivars. It is therefore essential to invest in organic breeding programmes for a broad range of crops. Additionally, upscaling production of plant reproductive materials adapted to organic production is challenging, especially for perennial crops.

Concerning wine production, an important regulatory obstacle to the introduction of resistant varieties under **denomination of origin** has recently been removed by the adoption of the new Common Agricultural Policy 2023-2027[9]. The new rules state that crosses between *Vitis vinifera* and other *Vitis* species is now allowed for wines under denomination of origin, while before only products obtained from *Vitis vinifera* could be protected by this appellation. This should encourage the adoption of grape varieties with resistance to fungal diseases (downy and powdery mildew), whose characteristics come from other species, either Asian or American (*Vitis amurensis, Vitis rupestris*...).

Market and consumer acceptance constitute another important obstacle. The wine market is characterised by several specificities that must be considered when thinking of the introduction of new disease-resistant grape varieties. Appellations play a major role in consumer preferences, as they give information on the geographical origin and organoleptic qualities. In this context, it is more difficult for unknown and/or non-traditional varieties to find their place on the market, especially as wine produced from resistant varieties is often associated with lower quality products in consumers' perception.

When it comes to alternative plant protection products to copper, a potential obstacle is **the societal acceptability of nature-identical active substances that are synthetically manufactured**. This may be

[9] Article 93, Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007

perceived by consumers (or even farmers) as not being compliant with the principles of organic farming related to respect for nature's systems and cycles or the responsible use of energy and natural resources. This issue concerns pelargonic acid, which may be extracted or synthetised, with the second option allowing larger quantities to be manufactured at lower cost. Synthetic manufacture of nature-identical substances is in specific cases a more cost-effective option for expanding production at an industrial level. The Organic Regulation (EU) 2018/848 does not forbid the use of natural substances that are synthetically manufactured (nature identical), and several such substances are already authorised in organic farming: all pheromones and the terpenes eugenol, geraniol and thymol.

Pelargonic acid could also be criticised because it is authorised as herbicide under Regulation 1107/2009. However, the doses are different depending on the use. For fungicide use, the doses are lower than for herbicide use.

Additional efforts are expected for farmers who would adopt the alternatives. Most, if not all, the alternative products to copper will be more expensive and should be used in combination with lower amounts of copper and probably also with other alternatives to reach the same level of protection as copper used as stand-alone treatment. This means that if farmers wish to use these alternatives, their production costs will increase. This could limit a wide adoption of these alternatives unless policy support actions compensate for this shortcoming.

Furthermore, from a practical point of view, the alternatives developed by RELACS will be more demanding to use than a stand-alone, all season copper treatments. The plant protection strategies developed in RELACS suggest using the alternatives at certain phenological stages as stand-alone products and/or in combination with copper and thus to focus copper use on the most susceptible growth periods. It is well-known and confirmed in RELACS trials, that application techniques and timing (supported by Decision Support Systems) are crucial for successful treatments. Plant health strategies including these alternatives are likely to require a higher level of technical expertise from farmers, who will need to be trained in this regard.

Finally, the alternatives developed by RELACS are far advanced but still at R&D stage. Therefore, **there are still knowledge gaps or grey areas** that may restrain the adoption of these alternatives.

First, the efficacy of the four plant protection products under rainy conditions is not yet fully explored and optimized, while this feature is key for effective disease control. In the current state of knowledge, the active substances are less persistent than copper and tend to be degraded and washed off by rainfall faster than copper. This means that under very conducive conditions in the open field (heavy infection pressure, repeated heavy rainfalls), the alternatives have their limits and are less efficient than copper. In greenhouses the performance is not affected by such conditions.

Secondly, it has been demonstrated that none of the alternatives covers all uses of copper, but together, the RELACS alternatives complementary tackle all investigated diseases. However, this raises two important questions:

- What is the impact of the multiple residues of these plant protection products on the environment and human health?
- What is the risk of resistance building linked to the combination of two or more alternative products with the same mode of action?

These aspects have not been investigated so far, while they are key elements of the long-term sustainability of any copper reduction strategy.

5.5 Strategies to overcome the obstacles

5.5.1 Already existing initiatives to reduce copper use

In 2018, the organic sector revised its strategy for the minimisation of copper in organic farming in Europe[10]. This strategy has two main aims: a precautionary risk minimisation for copper as well as for other external inputs, and a

[10] IFOAM Organics Europe's copper minimisation paper 'Strategy for the minimisation of copper in organic farming in Europe' (May 2018)

general reduction of the dependence on copper as well as on other external inputs thanks to an adaptation of plant health care strategies towards the basic principles of organic farming.

This strategy consists of the combination of four components:

- Increased cultivation of resistant or robust varieties;
- Optimisation of ecological processes and use of preventive measures;
- Lower application rate of copper;
- Use of alternatives.

Only the combination of these four different components will provide an efficient and resilient strategy for the minimisation of copper. It must be based on a system approach to ensure the long-term stability of the system.

Two complementary application practices are implemented by organic farmers in the context of the copper minimisation strategy: application splitting and a smoothing mechanism. Farmers split the application of copper, which means that in most cases copper is used with lower concentrations in combination with indirect measures and/or other products like for example sulphur. Therefore, the copper compounds are only applied in amounts as high as the maximum legal limit when severe infections are expected. With the smoothing mechanism, the maximum amount of copper allowed is defined for a period of seven years (rather than on a yearly basis), so farmers are strongly motivated to reduce copper in years with dry weather conditions in order to have more copper available in years with unfavourable conditions, if necessary. This kind of regulation strongly contributes to the fact that the full amount of copper allowed is only used on a few occasions and regions. The smoothing mechanism is an essential element of a successful minimisation of copper use.

5.5.2 RELACS policy recommendations to support copper reduction

The EU regulatory procedure for authorising **access to the market to plant protection products based on plant extracts** is a major bottleneck to making copper alternatives available to farmers. Since four of the alternatives to copper developed by RELACS are plant extracts, RELACS' policy recommendations focus on how to **facilitate the registration process for plant extracts** while rigorously assessing their risks. This should start with adapting data requirements for plant extracts to their specific characteristics, such as multiple compounds or composition variability, and updating the Commission's guidance document on botanical active substance used in plant protection products. Establishing an expert group that would be solicited for the risk assessment of botanical active substances could also speed up this step of the approval procedure.

With regards to the cost of preparing a dossier for the registration of an active substance, subsidising applications for niche markets or natural substances of public interest where the return on investment for a private company is low or non-existent would allow applications for alternatives that would otherwise not be made.

The establishment of an adequate and predictable regulatory framework also helps to **stimulate R&D activities on alternatives to copper**. Research is progressing well, however, no alternative is ready to be transferred to the market in the short term. Therefore, it is important to keep funding R&D on copper reduction, including alternative products, breeding programmes for resistant varieties, and other preventive measures.

Research projects must **involve the whole value** chain, to make sure that the alternatives developed by researchers will meet the expectations of farmers, consumers, and manufacturers. Promoting collaboration between researchers and manufacturers in the early stages of the development of alternatives makes it possible to anticipate the process of compiling the registration dossier, and thus save time on this lengthy stage. For instance, the research project may generate data that is required to complete the application dossier, with a range of trials covering different crops and locations. It also allows to see the limits of the tested alternatives and to make improvements under real production conditions.

Finally, **involving farmers through participatory research** facilitates a wide dissemination of these alternatives among practitioners. There is a strong demand from farmers to get involved in on-farm trials with copper

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https://www.organicseurope.bio/content/uploads/2020/10/ifoam_eu_copper_minimisation_in_organic_farming_may2018_0.pdf?dd alternatives and participatory plant breeding. EU policies should support the co-construction of knowledge between farmers and researchers and the development of such activities while limiting costs and risks to farmers.

Implementing strategies to reduce copper is likely to require additional efforts and costs for farmers due to several changes in cropping practices and input supply. **Farmers will therefore need to obtain access to both financial and technical support**. Advisory services will play a key role by providing guidelines and training farmers to the use of the new alternatives and their integration in the whole plant health strategy. Sufficient funding must be provided for these activities. Consideration should also be given to providing subsidies to farmers who implement copper reduction strategies. Member States should explore the possibilities offered by the Common Agricultural Policy in this respect. The use of decision support systems should be encouraged to optimise copper treatments as well as the use of alternatives. This could be achieved by facilitating farmers' access to these tools through financial support, or e.g. provision of software, training.

Some alternatives to copper may raise questions regarding their societal acceptability or consumer acceptance. **Developing communication campaigns** targeting farmers and consumers is a significant element of a successful strategy to reduce copper use. For farmers, this would aim to provide more explanations on the characteristics of the substance used which make it suitable for organic agriculture (e.g. pelargonic acid). For consumers, the aim would be to (i) raise awareness of the environmental qualities of produce grown with copper reduction strategies and to (ii) emphasize their responsibility as consumers to facilitate the transition towards more sustainable production systems based e.g. on the adoption of resistant varieties.

5.6 Reduction pathways/transformation

The results of the RELACS project allow to envisage a future in which more technical solutions are available for the gradual reduction of copper use. All four copper alternatives (larixyne, licorice, rare sugar, NEU 1143 F) explored under RELACS show promising activity against grapevine downy mildew and several diseases in other crops under field conditions. The four candidates vary in terms of efficacy depending on the crop/disease combination, but **none of the alternatives is as effective as copper under highly disease conducive conditions**. It is clear that **several alternatives will be necessary to cover the broad spectrum of copper use and to meet the requirements with respect to needed quantities**. At this stage, **the alternatives are most likely best integrated into a copper minimisation strategy** rather than a full replacement strategy. In low-risk conditions, complete replacement could be an option.

Reducing the use of copper is not only about replacing copper by other inputs. An effective copper reduction strategy is composed of:

- the cultivation of resistant varieties
- the implementation of preventive measures (enhancing functional biodiversity, crop management practices)
- the use of alternative substances
- lower application rates, notably thanks to Decision Support Systems and a smoothing mechanism explicitly integrated in the regulatory requirements linked to the authorization of copper.

RELACS provides solutions for one of the components (alternative substances), but the other components must also be further developed to support organic farmers to further reduce copper use.

Continuous research is needed to provide the necessary tools for copper reduction. More frequent extreme weather conditions due to climate change, and hence higher infection rates, necessitate more research.

Policy support for registration and implementation of alternatives as well as for market and consumer acceptance are crucial for adoption into practice. The alternatives will be more expensive than copper, which is relatively cheap considering its efficacy. Incentives will have to be found to encourage farmers to engage in further copper reduction.

6. Reduction of mineral oils

6.1 Problems associated with the use of mineral oils

Mineral (paraffin) oils are mixtures of hydrocarbons of various chain lengths (11 – 31 C atoms). They are an efficient tool to control a wide range of pests, among them mites, aphids, psyllids, leaf miners and scales. The mode of action of the oils is mainly suffocation when the oil moves into the breathing holes of the insects. Recently, it has also been shown that the paraffin oils are able to control insects by modifying their behaviour. The use of paraffin oils may also reduce the level of virus transmission of some aphids.

"Paraffin oils" are authorised as a 'group substances' in the organic regulation (EU) 2021/1165. Even if there is no restriction concerning the doses applied of paraffin oils in organic production, the organic farming associations, especially in central and northern countries, have long recognised that paraffin oil is a contentious input and that its use should be reduced, if feasible. Paraffin oils are considered as a contentious input because they are toxic for the pollinators and aquatic species (Nowak et al, 2019; EFSA, 2009) and because they are a by-product of crude oil.

Mineral oil use for pest control was drastically reduced in Northern and Central European countries by promotion of biocontrol and functional biodiversity or by replacement with less problematic compounds. However, under certain conditions and against some specific pests (mealybugs, aphids vectoring certain virus diseases, whiteflies, etc.) paraffin oil is occasionally still used. Paraffin oils are still used in Eastern European and the Mediterranean countries, albeit the extent is not quantified currently. In addition to pests in fruit crops, key pests such as white flies in vegetable crops cause far more damage in Mediterranean countries than in other regions. Agronomic practices and arthropod biocontrol can offer an alternative to mineral oils, however there is a need to find alternative solutions in term of selectivity (to be used in combination with biocontrol), high efficacy against specific insects (e.g. scales and mealybugs), outbreaks of high populations (e.g. in case of whiteflies) and vectors of viruses (as certain aphids).

It is important to highlight that none of the commercially available alternatives have a similar range of uses as mineral oils and no substantial reduction of its use is predictable at short term, particularly in view of the increasing difficulties due to climate change and the apparition of new invasive pests.

RELACS aimed to develop alternatives to mineral oil and integrate them in crop protection strategies. Two complementary approaches have been developed: plant extracts and a physical control method.

6.2 Tools and techniques developed in RELACS

RELACS's work on reducing the use of mineral oil focused both on perennial production systems (citrus) and greenhouse vegetable production.

For citrus production, RELACS has worked on two alternatives to control scales, thrips and mites. These are two plant protection products based on plant extract: orange essential oil and *Clitoria ternatea* extract.

For organic greenhouse vegetable production, a physical method was further developed by RELACS: an innovative whitefly control system based on vibrational mating disruption.

RELACS has also investigated the combined use of the two alternative products with the vibration disruption mating technique for greenhouse and citrus production.

The main characteristics of the two alternative products and the physical method studied in the RELACS project are presented in the following sections.

6.2.1 Orange essential oil

Description	Essential oil produced by cells within the rind of an orange fruit, which is composed mainly by D-limonene
Type of use	Insecticide for the control of Orange spiny whitefly (*Aleurocanthus spiniferus*) and Citrus mealybug (*Planococcus citri*) May have other type of uses: fungicide for several crops (grapevine, citrus and several horticultural crops) against mildew and powdery mildew; acaricide against *Eriophyes vitis* on grapevine; repellent.
Mode of action	Mainly contact insecticide: penetration of the insect's body, causing degradation of fatty compounds, thus disturbing the permeability of insects' and mites' exoskeleton (greater efficacy on insects with thinner cuticles) Additionally, D-limonene acts through fumigation and disturbs the respiratory system inducing neurotoxic effects on the insect.
Efficacy	Effective against citrus mealy bugs nymphs & females
Side effects	• Phytotoxic effects were reported on some plant species namely strawberries and cabbage • Potential negative impact on natural enemies
Historic of use & regulatory status	Citrus essential oils have been largely used for medicinal purposes, as well as for the protection of stored crops and as a pesticide. Orange essential oil is already approved as an insecticide, and marketed under the commercial name of PREV-AM® according to the regulation (EC) No 1107/2009 in some European countries such as France, Italy, Germany, Cyprus, Belgium, Spain, Poland, Austria and Romania.
Origin of raw material & production method	Orange essential oil is obtained from the hydro-distillation of orange by-products either from fresh or processed production. One source of orange essential oil is the fruit peel with a yield ranging between 0.5 and 5%. Citrus production is widely distributed, in sub-tropical and tropical areas, resulting in an all-year-long availability of products and thus a potentially wide availability of orange essential oil.
Scalability	Easy to reach
Costs	Affordable

6.2.2 *Clitoria ternatea* extract

Description	*Clitoria ternatea* is a plant belonging to the family of Fabaceae (subfamily: Papilionaceae), commonly named the "butterfly pea". It is known to be an excellent forage legume that can also be used as a cover crop and green manure.
Type of use	Insecticide for the control of Orange spiny whitefly (*Aleurocanthus spiniferus*) and Citrus mealybug (*Planococcus citri*). In Australia, this product is registered for the control or suppression of green mirids, silver leaf white fly (biotype b) and heliothis in cotton, for suppression of diamondback moth in brassicas.
Mode of action	C. *ternatea* extract acts through three mechanisms: • Direct toxicity: soft bodied-small larvae and nymphs are be killed directly when in contact with the insecticide.

	• Anti-feedant: The presence of the residues of the formulated product on treated plants deters pest feeding and results in pests starving. • Oviposition deterrent: The presence of the residues of the formulated product insecticide on treated plants can deter pest egg lay. Pests may avoid landing, or laying eggs on surfaces treated with the formulated product.
Efficacy	As effective as mineral oil against the first instar of juvenile whiteflies.
Side effects	No phytotoxicity caused by *Clitoria ternatea* on the sprayed plants has been reported.
Historic of use & regulatory status	In Australia, an ethanolic extract of *Clitoria ternatea* is registered and commercialized since 2016 for the use on cotton against whiteflies and thrips, under the commercial name "Sero-X Insecticide®". The registration dossier of the active substance is expected to be submitted to the EU soon.
Origin of raw material & production method	*Clitoria ternatea* occurs naturally in pantropical regions and can be cultivated in subtropical regions. *Clitoria ternatea* extracts are obtained through ethanolic extraction.
Scalability	Easy to reach, as the leguminous plant from which *C. ternatea* derives is adaptable to various soil and environmental conditions.
Costs	Price in line with other commercially available insecticides, although higher than the price of mineral oil.

6.2.3 Vibrations

Description	Vibration signal generating device, called "Vibro-plate" (prototype). The device consists of a square wooden plate, under which is placed an electrically powered mini shaker that emits vibrations.
Type of use	Physical method of insect control in greenhouses (whiteflies). In greenhouse, the plants are put on the vibro-plate, or the signal can be spread through metallic wires for crops that use wires as a part of the trellis system.
Mode of action	Vibrations are used to interfere with the communication of whiteflies, especially concerning mating behaviour.
Efficacy	Vibrations seems to reduce the population of whiteflies (studies still in progress)
Side effects	Side effects on beneficials (predators and parasitoids) must still be evaluated.
Historic of use & regulatory status	The use of semiophysicals (i.e., vibrational signals) for insect manipulation and crop protection is a novelty which is spreading worldwide. The use of physical stimuli (semiophysicals) for pest control is not regulated at EU level.
Origin of raw material & production method	Device's components: wood for the square plate + plastic layer for waterproof property; iron for the legs. Energy: in the greenhouse, the energy will be provided by electric cables, plugged in the facility whereas in the field it will be supplied by solar panels.
Scalability	The business model should include a company specialised in electronics and mechanics for the production of the devices, whereas the distribution would be handled by companies specialized in pest control.

Costs	For the device: • Greenhouse: 2-10€ / m2 • Open field: 3000-5000 € / ha (depending on plant density) Energy consumption: equivalent to a LED lamp; the device must remain on 24 hours a day for the duration of the protection of a crop.

6.2.4 Combination of alternatives

The combined use of these alternatives has also been tested in RELACS:

- It was observed that Orange Essential Oil combined with *Clitoria ternatea* causes lethal and sub-lethal effects on whiteflies, likely due to a synergistic effect between the two compounds on the pests.
- The use of the VibroPlate in synergy with the two plant extract alternatives seems to be very promising. The combination essential oils-vibrations aims at increasing the stress caused to the target pests and thus significantly reduces their populations and the associated damage to the crop.

6.3 Farmers' acceptance level of the alternatives proposed by RELACS

The acceptance level of farmers for the alternatives developed in RELACS to reduce the use of mineral oils was assessed during the RELACS national workshops (see section 3), taking place in Spain and in Italy.

6.3.1 Botanicals

Since orange essential oil is already authorised as a plant protection product in the EU, farmers provided feedback primarily on *Clitoria ternatea* extracts, either as a stand-alone treatment and in combination with orange essential oil.

Even before discussing alternatives to mineral oils, farmers emphasised the need to implement measures to enhance biodiversity and promote the presence of beneficial organisms, which help to control insect pests of citrus and greenhouse crops.

Overall, farmers consider that *Clitoria ternatea* extract could be an interesting alternative to mineral oil given its apparent efficacy and expected low environmental impacts. However, the current state of knowledge is not advanced enough, and they will need more data on efficacy and environmental impacts. Farmers are also very interested to have more data on the combined effects of *Clitoria ternatea* and orange essential oil, as it seems that it could have a higher efficacy.

It is interesting to note some differences in the perception of the alternatives between Spain and Italy. It seems that there is more interest for *Clitoria ternatea* in Spain than in Italy. A possible explanation could be a difference in awareness regarding mineral oil impacts on the environment. The negative impact of mineral oils on the environment is a well-known problem in Spain, therefore Spanish farmers would like to have access to alternatives to reduce the use of mineral oils. In addition, Spanish farmers seem to anticipate possible regulatory restrictions on the use of mineral oils due to the growing public awareness of these aspects. This makes the need for alternatives more urgent from their perspective. However, mineral oils are not yet the subject of any EU policy initiative or regulation to reduce their use, unlike copper. Nevertheless, despite their interest, Spanish farmers were concerned that since *Clitoria ternatea* is not endemic to Europe, its introduction could lead to undesirable effects on local fauna. Italian farmers did not question the origin of *Clitoria ternatea*.

6.3.2 Vibrations

Farmers are interested in the development of vibrational signals as an alternative to mineral oils, but they believe that this tool is more likely to be effective in greenhouses than in fields, since they have some doubts about its large-scale potential and use in open air. Furthermore, they would like to have more data on the impacts of the vibrations on non-target organisms.

The vibration device will need to be affordable for farmers to adopt it. Current cost estimations are too high, but farmers also believe it is plausible that upscaling production could reduce the costs sufficiently. However, they also highlighted that they would need financial and technical support to learn how to set up and use such tool.

Finally, a positive point for farmers is that this alternative does not need to be authorised at EU level to be put on the market, which means that it could be quickly available once it has gone from prototype to marketable product.

6.4 Obstacles to the adoption of the alternatives

Since orange essential oil is already authorised and used by farmers, this section focuses on *Clitoria ternatea* extracts and the vibrational device.

The alternatives to mineral oils developed by RELACS are promising, but there is **still a lack of data** to fully characterise efficacy, environmental impacts, integration in plant health strategy, costs and other key aspects to get these alternatives authorised and convince farmers to use them. In particular for the vibrational signals, there are important questions to solve regarding potential interferences with pollinators and beneficials. The combined use of plant extracts and playback of disruptive signals gave significant results in tests at small scale (few plants) in greenhouse, but these first results need to be confirmed with trials at larger scale.

Access to the market will also be challenging. The registration dossier of *Clitoria ternatea* extracts as active substance under Regulation 1107/2009 should be submitted soon. However, the registration process of botanical active substances is lengthy and costly. This the main obstacle to the availability of this alternative in the coming years. The vibroplate device does not need to go through a registration process in the domain of plant protection at EU level. But the difficulty here is that there is not yet a market for this tool. It is therefore necessary to create an outlet for this product in order to start large-scale production, which would reduce high production costs.

The adoption of the alternatives will involve **additional efforts and costs for farmers**. From an economic perspective, using *Clitoria ternatea* extracts will cost slightly more to farmers, but this remains acceptable for those who are willing to reduce their use of mineral oils. However, the price of the vibroplate device is very high for farmers and should be seen as a longer-term investment. This is a potential barrier to the adoption of this tool by farmers, who may consider it too expensive.

Furthermore, farmers will have to be trained to use these new alternatives, which will require more effort. Adapting the combination of different alternatives to the local farming systems is likely to be more difficult in practice than implementing strategies based on mineral oil treatments. In particular, farmers should be assisted in the setting up and maintenance of the vibroplate device. Although the device stays on throughout the growing season once started, it requires more attention to ensure that everything is running smoothly and that there are no failures.

6.5 Strategy to overcome the obstacles: RELACS policy recommendations

It is necessary to **improve the EU regulatory procedure for authorising botanical substances** as active substances to make *Clitoria ternatea* available to farmers. This should start with adapting data requirements for plant extracts to their specific characteristics, such as multiple compounds or composition variability, and updating European Commission's guidance documents on botanical active substances used in plant protection products. Establishing an expert group responsible for the risk assessment of botanical active substances could speed up this step of the approval procedure.

The alternatives to mineral oil developed by RELACS are well advanced, but **further research activities** are needed to complete the existing dataset and meet all the necessary requirements for bringing the product to market Sufficient funding should therefore be provided to conduct the remaining studies.

In the case of the vibroplate, it would be interesting to develop partnerships with commercial companies in the final test phases to anticipate the large-scale production of the device.

Farmers will need both financial and technical support to implement an optimised strategy combining the plant extracts (orange essential oil and *Clitoria ternatea* extracts) and the vibroplate device. The Common Agricultural Policy can be a powerful tool to provide financial support to farmers. Members States should explore the possibilities to propose investment support schemes in their Strategic Plan, targeting equipment that allows pesticide reduction, for which the vibroplate device would be eligible. Advisory services can also be strengthened through the CAP.

6.6 Reduction pathway/transformation

In the current state of knowledge, it is not possible to envisage a phasing out of mineral oils in organic farming, but the alternatives developed by RELACS show a good potential to reduce their use.

The mineral oil reduction strategy should include the following components:

- Implementation of measures to enhance biodiversity
- Use of alternative products to mineral oils based on plant extracts (*Clitoria ternatea* and orange essential oil)
- Use of vibrational signals, as a stand-alone method or in combination with the plant-derived alternatives.

Biodiversity measures are already widely implemented by organic farmers, as they rely on living ecosystems to protect their crops. Such measures can be further promoted and supported through various policies (Common Agricultural Policy, Birds and Habitats Directives, Sustainable Use of pesticides Directive), but they are already available to farmers who integrate them into a systemic approach to plant health.

To complete the strategy, the plant derived alternatives and the vibrational signals must be available to farmers. This will first require **further research** to finalise the last stages of development and confirm their efficacy and safety. **Sufficient fundings** must be ensured in this respect.

Then, the availability of the alternatives will depend on different conditions.

Citoria ternatea extracts will have to go through the EU registration process for active substances under Regulation 1107/2009. Given the costs and technical difficulties of preparing a dossier and the lengthy risk assessment procedure it is unlikely that *Clitoria ternatea* will be authorised in horizontal legislation before 2030. And once this has been achieved, it will still need to be authorised for organic production. **Adapting the registration process for active substances to plant extracts** would reduce the duration of the risk assessment to reasonable time frames, as envisaged by Regulation 1107/2009 (between 2.5 and 3.5 years), which would ultimately make *Clitoria ternatea* extracts available more quickly.

The uptake of vibrational signals in plant protection strategies is not expected to cause any costs or delays due to a registration process, but the production of the devices will have to be upscaled and the market developed. The purchase of the devices is likely to represent a significant investment for farmers, so **financial support** will be necessary. Different policy initiatives might provide financial incentives, either at EU level (Common Agricultural Policy investment supports) or at national level (e.g., tax incentives, co-funding).

Once available and affordable, the alternatives will be more easily adopted by farmers if they are trained to use them. The development of **demonstration farms** and tailored **advisory services** will contribute to this.

Finally, since the combination of plant-derived alternatives (orange essential oil and *Clitoria ternatea*) with vibrational signals seems the most promising option to reduce the use of mineral oils, it would be relevant to establish an action plan to coordinate all the measures listed above, which will facilitate their development, availability and adoption by farmers: research, registration, market acceptance, financial and technical support.

7. Discussions

Plant protection in organic farming is based on a systems approach, relying on enhancing biodiversity, preventive measures and the use of natural substances. These three components are important in order to improve the long-term resilience of the production system. The RELACS project focused mainly on finding alternative plant protection products for contentious inputs (copper, mineral oil), which is a necessary development. However, reducing the use of contentious inputs in organic farming is not about replacing one input with another, but about improving the whole production system by working on the three components all together. The alternatives developed by RELACS offer good prospects, which should be complemented by further research on preventive measures and biodiversity enhancement to fully optimise the system approach of organic farming to minimise the use of external inputs.

Given that most of the alternatives to contentious plant protection products developed by RELACS are plant extracts, and that the EU registration process for plant protection products based on botanicals is not adapted to this category, it seems clear that any further reduction in these contentious inputs will not be achieved until the registration process has evolved.

More generally, this registration process also hampers the European Farm to Fork strategy[11] and its target to reduce the overall use and risk of chemical pesticides by 50% by 2030. Achieving this ambition will only be possible if farmers have access to alternatives. The EU legislative framework on the authorisation of active substances and plant protection products should therefore evolve to propose a registration process adapted to natural substances. However, a successful reduction of chemical pesticides cannot rely solely on the availability of alternatives based on natural substances. A paradigm shift is needed towards a systemic approach to plant health, where preventive measures and biodiversity enhancement are key component of the plant protection strategy. The intelligent combination of these measures with the use of natural substances ensures the resilience of the production system, which is characterised by a reduced dependence on chemical pesticides.

[11] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Farm to Fork Strategy for a fair, healthy and environmentally friendly food system. COM(2020) 381 final.

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Annex I – Number and composition of participants in the national workshops

Number and composition of participants in the copper national workshops

	Belgium	Bulgaria	Hungary	Italy	Spain	UK
Advisors	2	20	3	6	4	4
Specialised farmers	5	4	3	3	3	2
Staff of organic farming associations	1	/	1	4	/	2
Members of organic farming associations	/	/	/	2	/	/
Specialised researchers	3	4	1	4	1	2
Certifying bodies	/	2	/	/	/	2
Policy makers	/	/	/	13	/	2
Manufacturers of PPPs	/	1	/	1	/	/
Others	/	/	/	/	1	/
TOTAL	**11**	**31**	**8**	**33**	**9**	**14**

Number and composition of participants in the mineral oil national workshops

	Spain	Italy
Advisors	4	8
Specialised farmers	1	4
Staff of organic farming associations	/	2
Members of organic farming associations	/	2
Specialised researchers	2	2
Certifying bodies	/	1
Policy makers	2	7
Manufacturers of PPPs	/	2
Others	/	/
TOTAL	**9**	**28**

Number and composition of participants in the nutrient national workshops

	Germany	Denmark	Hungary	Italy	Estonia
Advisors	2	2	4	4	NA
Specialised farmers	6	6	2	4	NA
Staff of organic farming associations	2	3	/	2	NA

Members of organic farming associations	/	6	/	1	NA
Specialised researchers	2		2	2	NA
Certifying bodies		1	/	2	NA
Policy makers	1	1	/	4	NA
Manufacturers of fertilisers	/	/	/	2	NA
TOTAL	**13**	**19**	**8**	**21**	**NA**

Number and composition of participants in the anthelmintic national workshops

	Germany	UK
Advisors	2	2
Specialised farmers	4	10
Staff of organic farming associations	2	2
Veterinarians	2	8
Specialised researchers	1	2
Policy makers	1	/
Others	/	2
TOTAL	**12**	**26**

Number and composition of participants in the antibiotic national workshops

	Germany	UK	Spain	France
Advisors	2	2		5
Specialised farmers	4	10	2	4
Staff of organic farming associations	2	2	1	5
Veterinarians	2	8	4	10
Specialised researchers	1	2	5	5
Certifying bodies	/	/	/	2
Policy makers	1	/	/	10
Others	/	2	/	/
TOTAL	**12**	**26**	**12**	**41**