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The State of Play of Copper, Mineral Oil, External Nutrient Input, Anthelmintics, Antibiotics and Vitamin Usage and Available Reduction Strategies in Organic Farming across Europe

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Abstract: Although input use in organic agriculture is strictly regulated, and significantly less contentious inputs are applied in organic than in conventional farming systems, copper, mineral oil, external nutrient input, anthelmintics, antibiotics and vitamins are still commonly used among organic farmers in the EU, partly due to the scarce availability of alternative products and the difficulty of implementing preventive strategies. Moreover, besides the direction set by the European Commission's organic regulation, only a handful of policy instruments exist at national levels to reduce the use of these contentious inputs. The purpose of this paper is to discuss the results of the RELACS EU-funded project about the current use of copper, mineral oils, external nutrient inputs, anthelmintics, antibiotics and vitamins in organic farming in the EU. The paper is based on six internal reports developed in RELACS which relied on international surveys, in-depth interviews, multiple case study methods, database-based calculations, secondary data sources, plus a survey independent from the reports to map existing policy instruments and voluntary initiatives in the EU aiming to reduce the use of the six input categories. As a result, the paper gives a comprehensive overview of the current consumption of the six contentious inputs within the organic sector, highlighting potential alternative strategies in the pipeline, available preventive measures and the willingness of farmers towards adopting these solutions. It also informs about specific policy instruments already in force, as well as about ongoing voluntary initiatives to reduce contentious inputs. Due to the current dependence of organic farming systems on the six categories of contentious inputs, any sudden phase-out or ban on their usage would do more harm than good to the organic sector. Therefore, gradual, data-driven reduction measures are needed, which require significant further investments in targeted research, and in policy support measures, with the active involvement of agricultural stakeholders.

Keywords: organic farming; contentious inputs; copper; mineral oils; soil nutrient management; anthelmintics; antibiotics; vitamins; reduction strategies; agricultural policy

1. Introduction

The organic sector has experienced tremendous growth in recent decades in the European Union. In 2019, organic farming was practiced on 14.6 million hectares, resulting in an 8.1% share of the total agricultural area of the EU [1]. The market for organics has also doubled in the last ten years, and it grew by 8% between 2018–2019 reaching €45.0 billion in the EU. With this, the European Union is the second largest market for organic products in the world [1]. The continuity of this growth will be further boosted until 2030 by the targets of the European Commission's Farm to Fork strategy. The Farm to Fork strategy sets the goal for organic farmland to reach a 25% share of the EU's total agricultural area by 2030, while substantially reducing the use of chemical inputs (pesticides by 50%, fertilizers by 20%) and nutrient loss (by 50%) [2]. In order to achieve the 25% organic farmland target, the European Commission has issued an Organic Action Plan in 2021 with 23 actions, including the intention to earmark funding under Horizon Europe for research and innovation projects on alternative approaches to contentious inputs and to foster the use of alternative plant protection products through farm advisory services [3]. In addition, the European Commission intends to support research and innovation on alternative sources of organic vitamins and to explore means to support the application for feed additives produced without genetically modified microorganisms (GMMs). Thus, the European Commission recognizes that a massive transition to and upscaling of organic and agroecological management practices is required, which should be supported by targeted research and extension support throughout Europe under the new funding programme Horizon Europe [4].

According to the principles and regulatory requirements of organic agriculture, the use of synthetic external inputs, such as synthetic fertilizers or chemical plant protection products, is forbidden. However, the application of natural or naturally derived substances as external inputs is acceptable if their active substances are included in the positive list of the annex of the regulation 889/2008 [5] and their use is justified [6]. In order to be included in the annex list of active substances, external inputs need to follow and need to be registered in the corresponding horizontal legislation [7], e.g., for fertilizers (2003/2003) [8], veterinary medicinal products (2019/6 [9] and 37/2010 [10]). Four main categories of external natural inputs, defined in the EC Regulation 834/2007, are notable: (1) plant protection products (PPPs) of plant or animal origin, microorganism or mineral derived substances such as copper fungicides or mineral oil; (2) fertilizers of microbial, plant or animal origin such as manure; (3) feed additives such as vitamins, supplements, and (4) veterinary treatments as antibiotics and anthelmintics [6]. Despite their permitted use, these external inputs have been under debate since the organic management standards were laid down by IFOAM Organics International in 1982 [11]. The contentiousness of these external inputs (specifically copper, mineral oil, external nutrient inputs (manure, fertilizers), anthelmintics, antibiotics and vitamins) lies in the evidence about their negative effects on the environment as they accumulate in soil or in the food chain or, more recently, in the difficulty of guaranteeing their genuine natural origin. Thus, although organic agriculture allows only a small proportion of selected external inputs (and in different levels) compared to conventional agriculture, among these there are still some that are contrary to the sustainability aspirations of organics [12–15].

Looking in more detail at the environmental costs of these inputs, both copper and mineral oils have been used for centuries as highly versatile, cost-effective plant protection products with relatively low toxicity compared to synthetic, chemical pesticides used in conventional agriculture [16,17]. However, copper persists in the environment and may accumulate in the soil, negatively affecting soil biota [18,19]. The mining of copper is also a highly environment degrading activity. Mineral oils are heavily toxic for pollinators and aquatic species [20]. In addition, considering the production of mineral oils, from the extraction of crude oil to its processing, it is definitely not a renewable or environmentally friendly product [21]. Antibiotics and anthelmintics can become toxic to many microorganisms and free-living nematodes as they build up in the environment [22–24]. Their excessive and regular use—often as a preventive measure—in conventional agriculture (preventive use is not allowed in organic agriculture) has resulted in resistant bacterial and parasitic strains [25,26] that pose severe risks not only to animal health and welfare, but also to human health. Indeed, the excessive use of antibiotics and anthelmintics in animals may increase the risk of transmitting drug resistant microorganisms to humans as in many cases the same antibiotics and anthelmintic drugs are used to control animal and human diseases.

With regards to residues, copper and mineral oil residues may also be present in organic products, although in comparatively lower amounts than in conventional products, nevertheless, they may still contribute to chronic human health risk. According to the European Food Safety Authority (EFSA) report, 6.5% of organic food samples contained measurable pesticide residues, still within maximum levels (copper and minerals oils included among other pesticides allowed in organic farming) in 2018, while pesticide residues were present in 44% of conventionally produced food samples [27]. EC Regulation 1981/2018 limits the use of copper to an average dose of 4 kg/ha/year over 7 years [28], while mineral oil usage is governed by EC Regulation 889/2008 [5]. National legislation or international private organic associations can further limit copper usage. For example, Denmark, Estonia, the Netherlands, Finland and Norway forbid the use of copper as PPP [29] and Demeter International Standard (The Biodynamic Federation Demeter International is the biggest certification body for biodynamic agriculture, which created the Demeter Standard to certify the production, processing of biodynamic agricultural activity and labelling of such products [30]) only allows its members to use up to 3 kg/ha/year [31], while Bio Suisse Standard (Bio Suisse is the umbrella organization for the organic farmers' associations in Switzerland, which also created and owns the private organic label and standard of the same name that certifies the production, processing of organic agriculture and labelling of organic products [32].) allows up to 4 kg/ha/year depending on the crop category [33].

Anthelmintic and antibiotic residues can be detected in animals and their produce for varying time periods, which necessitates withdrawal periods for animal products before they are suitable for human consumption [34,35]. Although, the EC Regulation 889/2008 on organics stipulates that a livestock management that strengthens the immune system must be practiced, and in case of disease occurrence homeopathic or phytotherapeutic treatments are preferred, antibiotics and anthelmintics are nevertheless acceptable to use when the previously mentioned methods are inappropriate, and with veterinary authorization to prevent animal suffering and ensure high welfare [5]. Due to very strict organic standards, the withdrawal period for animals administered antibiotics or anthelmintics is twice as long as in conventional animal farming, to further minimize the possibility of detecting residues in organic products [5].

Besides anthelmintics and antibiotics, lipophilic vitamins administered in organic livestock receive the harshest criticism. Following the organic regulation, livestock should obtain their vitamin requirements through their natural feeding regime. However, additional vitamins of natural and of synthetic origin can be given with restrictions if required, to meet basic nutritional requirements [5,6]. Although, dairy cows for instance can cover considerable part of their vitamin E requirements from natural sources [36], to ensure their metabolic antioxidant status, this vitamin is often supplemented synthetically. Another problem associated with B vitamins is that these are nowadays mostly produced by microorganisms that have been genetically modified [37] which is categorically forbidden in organic production. The lack of GM-free vitamin B manufacturing in Europe reinforces the vulnerability of the vitamin feed supply of organic farming [38,39].

The use of external nutrient inputs such as fertilizers and manures, often coming from conventional sources, jeopardizes the aim of organic farming to achieve on-farm recycling and circularity in the production system [40]. A carefully planned organic nutrient management includes a crop rotation using N-fixing crops and animal husbandry, which together allow that all nutrient loss during production is regenerated internally and returned through local organic sources [40]. However, in practice, organic arable farming is often decoupled from animal husbandry, thus macronutrients such as N, P and K are not available in appropriate amounts, and therefore they need to be returned via external sources [41]. Though, EC regulation 889/2008 limits these external fertilizer sources to (1) organic origin (coming from organic farming); (2) natural substances or (3) low solubility fertilizers, organic farmers often have to use exception rules, called derogations, and turn to conventional sources in the absence of adequate organic ones [5]. Moreover, although conventional fertilizers from industrial animal husbandry are strictly forbidden to use, this may be difficult to check and control, e.g., in case of commercial pelleted manure products coming from abroad. Until these inputs are phased out or substituted by better ones, organic farming will remain dependent and reliant on contentious inputs and on conventional farming. This hinders the further development of the organic sector and its potential to innovate and erodes consumer trust toward organic products. That is why it is paramount for the organic sector to address these issues and strive towards phasing out contentious inputs by providing alternative products and technologies, or better preventive strategies.

Although organic farming encompasses much more than just input use, this aspect is a pivotal element of the EU's agricultural future considering that increasing the share of organic farmland may be hindered by organics' dependency on contentious inputs. Recognizing the need to further accelerate the phasing-out of such inputs, a number of research projects (Organic-PLUS [42], CO-FREE [43], PrOPara [44], RELACS [45] investigated various contentious inputs used by organic systems and possible alternatives. These projects received funding from the EU Horizon 2020 research and innovation framework (Horizon 2020 was one of the biggest funding programme (79 billion euros) of the European Union dedicated to research and innovation between 2014–2020 [46]) and other financial instruments, including ERA-NET frameworks (ERA-NET was a funding instrument under the 6th Framework Programme (FP6) and Horizon 2020 with the aim to support the cooperation and organization of national research programmes [47]). One of the existing challenges is the lack of information on the level of current use of these contentious inputs by organic farmers. This gap in knowledge is addressed in the RELACS project [45] which aims at increasing the usage of cost-efficient, environmentally beneficial technologies that could further limit or completely replace the application of copper, mineral oils, external nutrient inputs, anthelmintics, antibiotics and vitamins in organic farming in the EU.

Therefore, this paper contributes to the current discourse with additional knowledge on the current use of these six inputs and their alternatives in Europe by summarizing the results of six internal reports [48–53] of the RELACS project. The results of some of these reports were published [54,55] while others are publications in progress [56,57]. The results presented here and in the RELACS reports fill in the gaps of European and national databases which to this day still lack consolidate information on the actual use of these inputs. In addition, this paper includes an overview of the existing policy instruments (compulsory and voluntary) and private initiatives for the reduction of contentious inputs' use in organic agriculture, resulting from an international survey we conducted within RELACS to support the elaboration of future agricultural policy measures in the EU.

2. Materials and Methods

Five out of the six RELACS reports used surveys and interviews with experts as primary data collection methods to gather information on the current use of contentious inputs in organics in the EU. Surveys and interviews were conducted to gain insight into the use of copper, mineral oils, anthelmintics and antibiotics and their available alternatives in organic farming, while for external nutrient (fertilizer, manure) input usage, a multiple case study method complemented with an expert panel consultation was applied. On the other hand, the report on vitamin usage relied solely on secondary data collection based on 2017 Eurostat [58] databases on all animal categories present in European organic farming. To determine the current practice on vitamin usage in the organic sector, figures from the feed-premix industry—more precisely from MIAVIT (the largest German company) [59]—were used (calculations performed in Microsoft Excel 2019, v16.0). The rest of the reports also used secondary data from international statistical databases, results of other research projects such as PrOPara or Organic Plus, available national databases on copper and mineral oil usage, and the European and Mediterranean Plant Protection Organization (EPPO) Global Database [60] for the homogenisation of names of diseases and registered plant protection products. In addition, for the UK only, anonymized organic control body records were used for evaluating veterinary treatment data (antibiotics and anthelmintics). Table 1 summarizes all secondary data sources used for the reports.

Table 1. Summary of secondary data sources used by the copper, mineral oil, external nutrient inputs, anthelmintics, antibiotics and vitamin reports.

Contentious Input Category	Secondary Data Sources Used	Reference of the Data Source
Internal report on the use of copper and its alternatives in organic crop production	European and Mediterranean Plant Protection Organization (EPPO) Global Database	[60]
	European Commission's pesticide database	[61]
	The World of Organic Agriculture. Statistics and Emerging Trends 2019. Research Institute of Organic Agriculture FiBL and IFOAM-Organics International	[62]
	FiBL statistics	[63]
	Commission Regulation (EC) No 889/2008 Annex II	[5]
	Partner country's national pesticide databases: Netherlands	[64]
	Partner country's national pesticide databases: UK	[65]
	Partner country's national pesticide databases: Switzerland	[66]
	Farming Statistics Final Land Use, Livestock Populations and Agricultural Workforce, 2018—DEFRA England	[67]
	Previous survey experiences obtained from Organic Plus project	
Internal report on the use of mineral oil and its alternatives in organic crop production	European and Mediterranean Plant Protection Organization (EPPO) Global Database	[60]
	European Commission's pesticide database	[61]
	FiBL statistics	[63]
	Commission Regulation (EC) No 889/2008 Annex II	[5]
	Partner country's national pesticide databases: Italy	[68,69]
	Partner country's national pesticide databases: Spain	[70]
	Partner country's national pesticide databases: Greece	[71]
	Partner country's national pesticide databases: Turkey	[72]
	Partner country's national pesticide databases: Egypt	[73]
	Previous survey experiences obtained from Organic Plus project	
Internal report on the use of external nutrient inputs and their alternatives in organic crop production	Standard values of input and crop nutrient contents	[74]
	Product descriptions, in-country norms as well as the USDA 'Crop Nutrient Tool'	[75]
	Estimation of the N input from BNF (biological nitrogen fixation) when yields were recorded in German and Swiss cases	[76,77]
	Estimation of the N input from BNF when yield were not recorded	[78–85]

Table 1. *Cont.*

Contentious Input Category	Secondary Data Sources Used	Reference of the Data Source
Internal report on the use of anthelmintics and its alternatives in organic livestock production	Unpublished datasets from research colleagues in the field, including colleagues from FEVEC (France) and the University of Ghent (Belgium). These datasets have helped with the interpretation of the survey data	
	Data previously collected in other EU funded projects (e.g., Core Organic Plus projects: PrOPara, HealthyHens and CorePig) on farmers' perception and use of alternative parasite control measures,	
	Anonymized organic control body records on veterinary treatments from the UK	
Internal report on the use of antibiotics and its alternatives in organic livestock production	Anonymized organic control body records on veterinary treatments from the UK	
Internal report on the use of vitamins and its alternatives in organic livestock production	Figures of different livestock in EU organic systems recorded by EUROSTAT, 2017	[58]
	Feed intake rates suggested by literature for laying hens	[86]
	Feed intake rates suggested by literature for broilers	[87]
	Feed intake rates suggested for pigs by the German Society of Nutrition Physiology	[88]
	Feed intake rates suggested by literature for rabbits	[89]
	Supplementation figures published by FEFANA (European Association of Specialty Feed Ingredients)	[90]
	Supplementation figures published by MIAVIT	[59]

2.1. Multiple Case Study Methodology and Expert Consultation for External Nutrient Inputs' (Fertilizer, Manure) Use in Organic Farming

A multiple case study method was conducted involving 71 organic farms, 8 cases and 7 European countries (Denmark, Estonia, Hungary, UK, Germany, Italy, Switzerland) to gain deeper insight into the use of external nutrient inputs in Europe. The selection of case countries aimed to reflect the diversity of European organic farms based on their historic experience with organic practice (UK, DE, CH—long history of organic practice vs., currently developing practice such as in HU, EE) and to represent typical cropping systems (arable, mixed or vegetable systems) with no or few animals (Table 2). This selection was made, because challenges with nutrient acquisition were deemed to be highest in these farm categories. Data was collected from in-country interviews with farmers from the selected 71 organic farms to quantify inputs and outputs for the farm covering a three-year period (2015, 2016, 2017) and the cropping history and livestock held at the farm (detailed questionnaire can be found in Appendix A). The interview responses were quantitatively assessed using Excel (2019, v16.0).

To evaluate nutrient management practices on selected farms, the combination of farm gate nutrient budget calculation covering three years and the quantification of nitrogen inputs from biological nitrogen fixation were applied. Nutrient budgeting is a widely used, effective tool to assess the performance (nutrient input and outputs) of organic farming systems [91–93]. Only the budget for the main macronutrients, N, P and K, was calculated (The standard values of USDA Crop Nutrient Tool, country-specific norms, values developed by Möller and Schet and product description were used as basis for evaluating N, P and K inputs and crop nutrient content.) for each country through the quantification of nutrient flows and deficit or surplus was calculated using the formula $\sum$Outputs − $\sum$Inputs, in Microsoft Excel (2019, v16.0). The estimation of biological nitrogen fixation (BNF) was based on the yield data of nitrogen fixing crops made available by the selected organic farms (In case of documented yields, the standard values of nitrogen fixing crops were used. In case of absent yield documentation, an estimate of N-fixation/ha was applied based on the standards found in literature (Table 1)). The total nitrogen inputs of farms were supplemented by the data gathered from nitrogen input resulting from fixation. In addition, the proportion of N, P and K inflows for five categories of input sources were calculated: (1) manures from organic farms, (2) manures from conventional farms, (3) nutrients from other organic inputs, (4) nutrients from mineral sources and (5) feed. Nutrient outputs were assessed based on the estimated nutrient content in farm products and other outputs.

Table 2. Overview of the organic farms in each case area with values of average farm size, stocking rate, and years of organic production and the type of the farming system. Numbers in parenthesis for average farm size, stocking rate, years of organic production present the range of values.

Country	Farms	Average Farm Size (ha)	Average Stocking Rate (LU ha^{-1}) *	Average Years of Organic Production **	Farming System Types (Arable, Vegetable or Mixed)
Denmark	7	117.0 (13.8–321.7)	0.6 (0.1–2.3)	18.2 (8–31)	Arable (3). Mixed (4)
Estonia	11	402.7 (163.8–615)	0.2 (0.1–0.42)	15.2 (8–23)	Arable (6). Mixed (5)
Hungary	10	98.0 (7.2–243.0)	2.0 (1.6–2.4)	14.9 (6–16)	Arable (8). Mixed (2)
UK	8	265.4 (20.9–1163.3)	1.5 (0.9–2.8)	24.0 (19–34) ***	Mixed (8)
Italy	5	27.1 (5.2–42.5)	0	9.0 (1–22)	Arable & vegetable (5)
Switzerland	10	20.9 (7.6–37-3)	1.3 (0.7–2.2)	20.8 (10–30)	Arable (3). Mixed (7)
Germany (N)	10	160.2 (24.4–422.0)	0.4 (0.1–0.9)	18.0 (5–36)	Arable (6). Mixed (4)
Germany (S)	10	60.1 (15.0–125.0)	0.6 (0.4–0.7)	22.6 (10–32)	Arable (6). Mixed (4)

* Average is for mixed farms only. ** As of 2019. *** Missing data for 3 farms in UK.

Moreover, an expert panel was invited in each of the case countries to provide qualitative, expert opinion on nutrient supply and management in organic systems. In total 22 experts were recruited with help from farmer organizations participating in the RELACS project. Three questions were posed to groups of experts (researchers, advisors/consultants, people involved in legislation or certification, and representatives from the consumer side) in each case country: (i) knowledge of in-country nutrient supply challenges in organic systems, (ii) the extent of reliance of organic farms on contentious inputs and (iii) the experts' view on potential future sources of nutrient supply to organic farms. The expert input was analysed using basic content analysis, and responses were coded. Based on an iterative process a consensus between experts was largely achieved, although regional differences in outlook were clearly apparent. Expert opinion was used to complement, triangulate and discuss the farm-scale findings.

2.2. International Surveys and Complementary Data Collection

Four international surveys were conducted to gain further knowledge on country-specific current use of copper, mineral oils, anthelmintics and antibiotics and on the availability of alternatives to their use. Table 3 summarizes the common characteristics of the four surveys based on the theme, number of respondent countries, complementary data collection methods, total number and type of respondents and the data requested from respondents. The original questions of the surveys distributed to the respondents are listed in Appendices B–D. The consolidation of all interview results was performed by content analysis and were assessed in Microsoft Excel (2019, v16.0). The Pearson correlation coefficient for the copper use was calculated using the software IBM SPSS Statistics (2015, v23.)

Table 3. Common characteristics of the international surveys (theme, number of respondent countries, complementary data collection methods, total number of respondents, type of respondents and the data requested from respondents) conducted to gain insight into the use of copper, mineral oil, anthelmintics and antibiotics in organic farming.

Theme of the Survey	Number of Respondent Countries	Complementary Data Collection	Calculations Used	Total Number of Respondents	Type of Respondents	Data Requested from Respondents
Copper use, reduction strategies and availability of alternatives	12 countries: Switzerland, France, Hungary, UK, Spain, Italy, Norway, Bulgaria, Estonia, Belgium, Denmark, Germany	-	To estimate the total permitted and total practiced use in the surveyed countries: permitted use/crop x total organic area/crop = total permitted use AND estimated practiced use/crop x total organic area/crop = total practiced use	>20	Researchers, farmers' associations, extension officers	Legal status of copper usage and the availability of alternative products, description of the most frequently applied crop protection strategies in key crops, brief history of copper usage from the last 10 years, expert assessment on alternatives of copper reduction without affecting yield
Mineral oil use, reduction strategies and availability of alternatives	6 European Countries: Italy, Spain, Belgium, Switzerland, Greece, France. 6 non-European countries: Algeria, Morocco, Lebanon, Turkey, Egypt and Tunisia	Additional in-depth interviews conducted at ministerial level and at farmers groups in non-EU countries through phone interviews.	Estimated use of mineral oils regarded only the total permitted. It was presumed that the different countries used all the products.	89	Researchers, farmers, experts, representatives of plant protection services	Confirming data available in EU and national databases, mineral oil usage and control strategies in organic production, availability of alternative products and strategies (best practices) of reduction
Anthelmintics use, reduction strategies and alternative therapies	16 countries: Belgium, Croatia, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Lithuania, Poland, Romania, Spain, Sweden, Switzerland, UK	Data obtained from the ProPara research project, additional detailed survey including only organic farmers from the UK, access to Soil Association (anonymised) databases on supplementary requests for medicines 2017–2018, A literature review	Number of anthelmintic treatments input/country = (% anthelmintics requested in health plans calculated as % of total heads of livestock) + (% supplementary requests for anthelmintics calculated as % of total heads of livestock) AND weighted average of anthelmintic treatments across 16 countries = total anthelmintic treatments for 16 countries ÷ total heads of livestock for 16 countries	139 (organic expert survey) + 356 (UK farmer survey)	Organic inspectors, advisors, livestock health practitioners + organic farmers from the UK	Organic expert survey: requirement for anthelmintics on inspected farms: included in health plans (Health plans are tools used by most of the European organic certification bodies that document the requirements of different treatments of animal diseases by the farmers for 12 months. In case the treatments planned for 12 months is insufficient, farmers can request additional veterinary treatments (antibiotics, anthelmintics) outside their Health plan) and as supplementary requests UK farmers survey: use of anthelmintics (frequency, proportion of stock treated), presence of anthelmintic resistance, methods for monitoring parasitic infection on farm, use and openness to alternative control strategies

Table 3. *Cont.*

Theme of the Survey	Number of Respondent Countries	Complementary Data Collection	Calculations Used	Total Number of Respondents	Type of Respondents	Data Requested from Respondents
Antibiotics use, reduction strategies and alternative therapies	16 countries: Belgium, Croatia, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Lithuania, Poland, Romania, Spain, Sweden, Switzerland, UK	Additional survey including only organic farmers from the UK, access to Soil Association (anonymised) databases on supplementary requests for medicines 2017–2018	Number of antibiotics treatments input/ country = (% antibiotics requested in health plans calculated as % of total heads of livestock) + (% supplementary requests for antibiotics calculated as % of total heads of livestock) AND weighted average of antibiotic treatments across 16 countries = total antibiotic treatments for 16 countries ÷ total heads of livestock for 16 countries	139 (organic expert survey) + 356 (UK survey)	Organic inspectors, advisors, livestock health practitioners + organic farmers from the UK	Organic expert survey: requirement for antibiotics on inspected farms—included in health plans and as supplementary requests; UK farmers survey: use of antibiotics (frequency, proportion of stock treated), most common diseases requiring antibiotics, presence of antibiotic resistance, use and openness to alternative control strategies

2.3. Survey on Existing Policy Instruments and Voluntary Initiative to Reduce the Use of External Inputs in Organic Farming in the EU

Finally, an international survey to map existing policy tools and voluntary, public/private initiatives based on their geographic scope, nature, working mechanisms and respondent's satisfaction levels for the reduction of contentious input use in organics in the EU was conducted including all six input categories (survey questions listed in Appendix E). The survey was analysed by descriptive statistics on initiatives as cases (a person, who added more initiatives to the survey was included in several rows in the dataset). Frequencies and percentages were calculated to describe the distribution of investigated discrete variables separately and in combinations (contingency tables) for the six input categories examined (copper, mineral oils, vitamin, anthelmintics, antibiotics, external fertilizer input). The software packages used were IBM SPSS v25 and Microsoft Excel 365, v16.0).

3. Results

3.1. Current Use of Copper and Its Alternatives in Organic Crop Production

With regard to copper use in organic farming in the EU, the statistical review complemented by survey results reflect 115 crops and crop categories covering 2.9 million ha of arable and horticultural land in total and provide a comparison of their authorized and effective copper use. Results show that copper is most widely allowed on apple (allowed in 12 countries), grape (12 countries), pear (eleven countries), potato and plum (eight countries), and cherry, and strawberry (seven countries each) in the surveyed 12 countries. The degree of copper usage within legal limitations differs greatly between crop categories. For example, effective copper use in grape, potato and tomato in most countries is close to legal limits, while limits for soft fruits are rarely exploited by farmers. Overall, in 56% of the total allowed uses (crops x countries), farmers use less than 50% of the legal maximal amounts. The total permitted use (t/year) and the total estimated use by organic farms for the 12 countries were calculated by multiplying the allowed/used amounts per crop and country (kg/ha/year) by corresponding organic areas. In the twelve surveyed countries, organic farmers used around 53% of the total permitted amount of copper, corresponding to approximately 3200 ton/year (Table 4). Italy, Spain and France use the majority of copper—due to their large areas of horticultural production, especially vine and, in the case of Italy and Spain, olive area—while Norway, Belgium, the UK and Switzerland use the lowest amounts.

Table 4. Total allowed copper use (t/year) and estimated effective copper use (t/year) in 12 European countries.

	Belgium	**Bulgaria**	**Denmark**	**Estonia**	**France**	**Germany**	**Hungary**	**Italy**	**Norway**	**Spain**	**Switzerland**	**United Kingdom**	**Total**
Copper use allowed	4.0	248	0	0	546	91	34	3253	0.6	2038	10.4	11.5	6236
Copper use by organic farms	3.8	67	0	0	473	42	22	1556	0.5	1081	7.1	6.2	3258
Proportion of allowed amount used by organic farms (%)	94	27			87	46	64	48	78	53	68	54	52

As for estimating the copper use in different crop categories in the 12 countries, the report concluded that olive and grape production accounts for the majority (69%) of the total copper use. Figure 1 summarizes the total estimated copper use/year in the 12 countries in different crop categories.

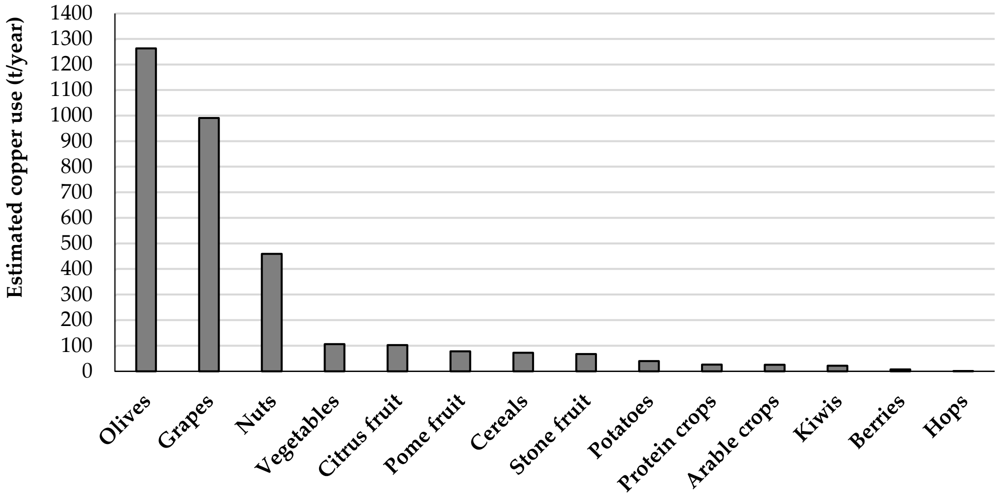

Figure 1. Total estimated copper use (t) per annum in organic farming in 12 European countries. Crops were aggregated into crop categories.

The survey asked about the availability of alternative products and preventive strategies. Based on the responses, grape vines have, at present, the most alternatives to replace copper and hazelnut, brassicas, walnut and cucumber are the crops which do not have, or have just a few, alternatives to copper. In addition, the survey revealed a wide range of copper alternatives to control different crop diseases, but there are no alternatives at present that would be as effective and applicable to all of them, as copper is. Nevertheless, some plant extracts (e.g., Laryxine (larch extract), tagatose (a rare sugar) or inorganic compounds such as calcium carbonate and calcium hydroxide seemed promising for the respondents in terms of efficacy and/or range of use. With regard to preventive strategies, resistant crop cultivars and rain shelters were considered the most effective methods against diseases by the respondents. However, the use of resistant cultivars remains yet underexploited due to the time and resource-intensive nature and low returnability of breeding efforts, especially in long-standing crops such as olives.

Our study—to our knowledge—for the first time gives an overview of which copper quantities need to be replaced in European organic farming and for which crops there is a particular need for research, development and advice. Considering the staggering amounts of copper currently used, it is clear that replacement will only be feasible if several affordable alternative plant protection products are brought to the market in sufficient quantities, while fully implementing all preventive strategies and decision support systems.

3.2. Current Use of Mineral Oil and Its Alternatives in Organic Crop Production

Regarding the use of mineral oils, most of the surveyed countries have authorized them, depending on climate, most often for citrus followed by pome and stone fruits, grapes, ornamentals and berry fruits, except Portugal where they are only authorized for citruses and fruit trees. France permits a very wide range of usage for citruses, seed potatoes, apple, and fruit trees. The legal dosages permitted for different uses by countries are listed in the EPPO database, but it is clear that the concentrations and residues are not regulated and often the maximum permitted amounts are not specified. In the Euro–Mediterranean countries, mineral oil is mainly used against the pests and diseases of citruses, olives and sometimes tomato, including greenhouse treatments. In Italy, for citruses, mineral oil is used 1–2 times/year, depending on the presence of pests, with a maximum application rate of 2500 L/ha. In Spain, a maximum of 90 L/ha/year can be applied, while in Turkey the application rate is 600–1500 mL/100 L water. In other non-EU Mediterranean countries, the use of paraffinic oils is also widespread.

As for the alternative products and strategies, the results of the survey showed that contrary to copper, mineral oil is relatively easily replaced with other natural substances.

According to the respondents the following main points were raised: most of the participants were not aware of the future banning of paraffinic oils, considering them equal or similar to the other hydro carbides allowed as co-formulants in organic plant protection products. At the same time the level of substitution is high in some countries, since farmers are using natural oils (not paraffinic) coming from crop extracts (orange oil for example). In the meantime, considering that the most important use of paraffinic oils is for citrus pests, the main alternative is the use of beneficials (parasitoids and predators) in open field conditions. Finally, from the direct interviews, it appears that paraffinic oil can be easily substituted with authorized inputs in European countries, while there is a serious lack of information on novel and alternative products in non-European countries.

The survey also pointed out the possibility that paraffin oils might be soon abandoned in organic farming in EU Mediterranean countries for the large amounts of alternatives that are available, such as oil crop extracts, which are cheaper, easy to use and have been introduced at local level by local advisory services in cooperation with research centres. However, the lack of knowledge of these alternatives persists in non-EU Mediterranean countries.

3.3. Current Use of External Nutrient Inputs (Fertilizer Products and Manure) and Their Alternatives in Organic Crop Production

Across all 71 interviewed farms, a surplus of N was detected, while there was a rather balanced budget for K and P with a small surplus for K and a small deficit for P. However, the variance between countries and also between farms in the studied countries was very high. It is notable that the variance was higher for N and K as compared to P. The highest N surpluses were detected in Switzerland, followed by North Germany and Denmark, while low surpluses were found in South Germany. For P, the picture is different; here the highest surpluses were found in Italy and the biggest deficits in South Germany and Hungary. The inventoried farms of three countries had an average surplus of P. For K, three countries' averages showed surpluses (Denmark, North Germany and Italy), while the highest deficits were found in Estonia and Hungary. The differences in farming intensification were also reflected in the provisioning of external inputs. For example, Danish farms acquired on average 68 kg N from outside sources from sources less than 20 km away, whereas Hungarian farms acquired on average 16 kg N from sources most often more than 150 km away. Across all farms, the average proportion of nitrogen sourced from conventional manure was 16%, again with considerable variation across countries (northern Germany 4%–Hungary 43%).

The reliance on BNF for the supply of N to the farms also differed highly among countries and farms ranging from 0–100% of N supply through legumes. A difference between countries was observed. While Estonian farms relied on average over 97% on BNF for their N supply, inventoried farms in Denmark had a reliance on average of just below 30%.

The nutrient balance showed that many farms have a low output. The average N output was 55 kg N ha^{-1}, while the median value was 44 kg N ha^{-1} across all countries. In the more intensive production found in Denmark, Switzerland and northern Germany, where farms generally use substantial amounts of inputs, the average N output was 79 kg N ha^{-1}, while the median value was 74 kg N ha^{-1}.

Expert input from the respective countries generally aligned with the observable trends in the data. Regarding the sustainability of nutrient supply, a synthesis of expert opinion identified key areas of concern. The first is that there is an undersupply of external fertilizer inputs that are permitted in organic systems, particularly for stockless holdings. Secondly, the purchase of external inputs to balance nutrient needs is costly for farmers, and farmers therefore rely strongly on ensuring enough legumes in the rotation to meet soil fertility needs (for N). However, focusing on ensuring a sufficient N supply can cause P and K deficiency which, in failure to address, will worsen slowly over time and at some stage can become very problematic for producers. Thirdly, the quest for reliable supplies of 'organic' sources of sufficient nitrogen in balance with other limiting nutrients (e.g., from composts, vinasse, seaweed, digestates) is fraught with difficulty because these sources are highly variable (in terms of nutrient content) and difficult to manage as their effect on soil function and nutrient release processes is hard to predict, and they can result in oversupply of some nutrients.

3.4. Current Use of Anthelmintics and Antibiotics and Their Alternatives in Organic Farming

The surveys for anthelmintics and antibiotics were both conducted among the same participants through the same distribution channels. Since they have the same general characteristics and number of respondents, the results of the two surveys are presented together in this section. To the best of our knowledge, this is the first study were the current use of anthelmintics and antibiotics is surveyed at such a large scale in Europe. Reaching out to organic inspectors rather than individual farmers allowed us to survey a larger number of farms, as each inspector is responsible for many farms. The surveys of organic inspectors were disseminated Europewide and had 139 responses in total from 16 European countries, who were responsible for 17,719 organic farms (Table 5). There were considerable country-specific differences in the proportion of farmers requesting the use of both anthelmintics and antibiotics, either as part of their health plans, or as supplementary, additional requests (Figures 2 and 3).

Table 5. Antibiotics and anthelmintics survey responses by country, number of inspector responses and number of farms covered by inspectors.

Country	No. Inspector Responses	No. Farms Covered by Inspectors
Belgium (BE)	3	317
Croatia (HR)	1	74
Czech Republic (CZ)	1	1850
Denmark (DK)	3	410
France (FR)	45	5350
Germany (DE)	30	4790
Greece (GR)	1	200
Ireland (IE)	2	328
Italy (IT)	1	500
Lithuania (LT)	5	549
Poland (PL)	2	60
Romania (RO)	1	150
Spain (ES)	10	556
Sweden (SW)	2	165
Switzerland (CH)	1	130
UK	31	2290
Total	139	17,719

In most of the countries surveyed, a large proportion of farmers included anthelmintics and antibiotics in their health plan (see blue bars of Figures 2 and 3), nevertheless, the supplementary treatment requirements were also high for some of them (data not shown, e.g., in Ireland, Romania, Italy, France, Spain and Croatia). Inspectors from certain countries, such as CZ, LT and PL, indicated that a lower proportion of their farmers included anthelmintics and antibiotics, either in their health plans or as supplementary requests, compared to other investigated countries. Inspectors from Greece indicated that almost 100% of their farmers had requested the use of anthelmintics in their health plan, whereas in Denmark, a small proportion of farmers included anthelmintics and antibiotics in the health plans. It should be noted that these graphs do not reflect total drug input, as there was no information on the number of animals used or their frequency of use.

Figure 2. The percentage of organic farms requesting antibiotic treatments in health plans, and supplementary requests 2017–2018 as defined in the survey.

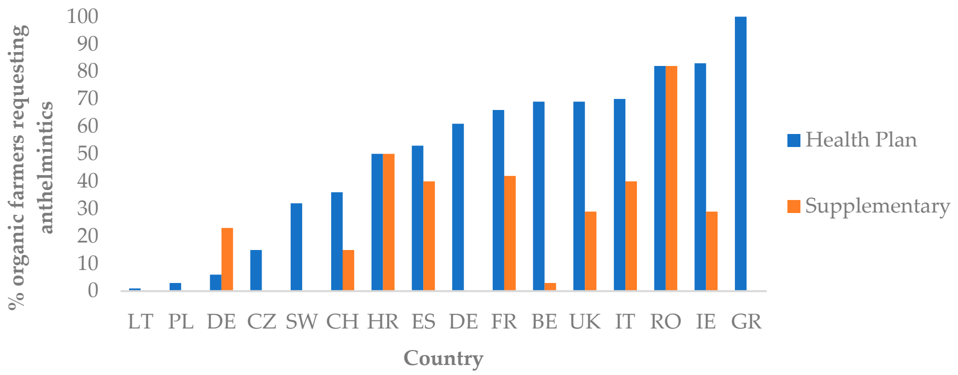

Figure 3. The percentage of organic farms requesting anthelmintic treatments in health plans, and supplementary requests 2017–2018 as defined in the survey.

In order to gain an insight into the anthelmintic and antibiotic input in European organic farms, we estimated the weighted treatment ratio/animal/year across the 16 countries. The ratio for anthelmintics was 0.86 treatments/animal/year, while for antibiotics it was 0.7. Given the number of organic livestock is 53 million in the EU, it was concluded that an estimate of approximately 45.5 million anthelmintics treatments and 37 million antibiotics treatments may have entered EU organic systems between 2017–2018.

The additional survey of organic farmers conducted in the UK was filled out by 356 respondents for each treatment category. In brief, 61% of the respondents confirmed anthelmintics usage, whereas 39% of the respondents confirmed antibiotic usage in the last year, which is reinforced by the data of the inspectors' survey that estimated the UK farmers' anthelmintic usage at 69% and the antibiotic usage at 41% based on their health plans. The majority of the UK farmers only used anthelmintics one or two times/year, which is in agreement with the results of the PrOPara project that surveyed the anthelmintics usage in eight European countries. The project showed a difference between the number of treatments and livestock categories [87]. Lambs required more treatment than dairy and beef cattle which was in agreement with the Organic Control Body records in the UK (Soil Association). Out of the 533 supplementary requests for anthelmintic use, 365 requests were for sheep, and 149 for cattle. This indicates that helminth control constitutes a considerable input of veterinary medicines and is a big health and welfare concern in organic livestock farming, particularly for sheep.

Antibiotics usage was also between one and two times/year, depending on the individual disease occurrence; antibiotic use more than three times/year, would have resulted in a violation of the regulation on the sales of organic products. Out of the 529 supplementary requests for veterinary medicines only a small portion (less than 1%) was used for antibiotics.

In addition, the UK antibiotics survey identified 23 health problems that are usually treated with antibiotics, of which foot problems, mastitis, respiratory infections, interventions during parturition and eye infections were the five most frequently mentioned issues. The usage of alternative therapies instead of antibiotics turned out to be relatively low, 16% among the respondents confirmed such treatments, but many were open to try out alternatives, while around 5% would never try them at all (Figure 4).

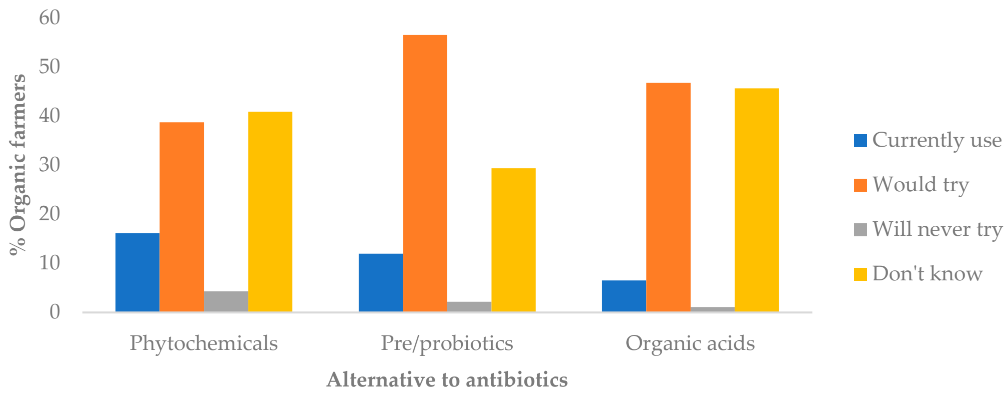

Figure 4. Percentage of UK farmers currently using or open to trying alternative treatments to reduce the need for antibiotics.

3.5. Current Use of Vitamins and Its Alternatives in Organic Livestock Production

Vitamins are regularly added to vitamin–mineral premixes, which are added either to concentrate feeds or, particularly for ruminants, provided as separate powders or licking blocks to the animals in barn or on pasture. These premixes are produced and added to feed formulations by the feed industry, i.e., usually not on the farm. For this reason, in most of the cases the decision regarding concentrations of supplemented vitamins and minerals is not made by the farmer but by the feed mill. The most common collection of supplement recommendation for livestock is that provided by the European Association of Specialty Feed Ingredients and their Mixtures (FEFANA) [90], which is almost completely reflected in the figures of MIAVIT [59] the only German premix producer, which also delivers organic premixes. The British and French producers we contacted also indicated that they follow the FEFANA guidelines. A 20-year-old Spanish survey on vitamins in chicken feed [94] showed measured vitamin concentrations, which match well with current FEFANA regulations regarding B-Vitamins, but are clearly lower regarding vitamin E. The latter shows that, due to increasing performance and thus metabolic rates of animals, the feed producers currently add high safety margins. As long as no specific data and recommendations for vitamin supplements to organic livestock exist, there is no reason to use different supplementation levels for the organic sector. This was the consistent response from all feed producers in Germany, Switzerland, France and UK.

Based on this background, we assumed that the current use of vitamins in European organic livestock must be calculated by the number of respective animals multiplied by the current recommendations for vitamin supply used by the feed producers.

For example, Figure 5 shows the annual use of vitamin E in Europe, and Figure 6 shows the picture for vitamin B2, both distributed by animal species calculated as part of the RELACS project. This illustrates that the relevant issues to solve are concerning live livestock species very differently, depending on the type of vitamin.

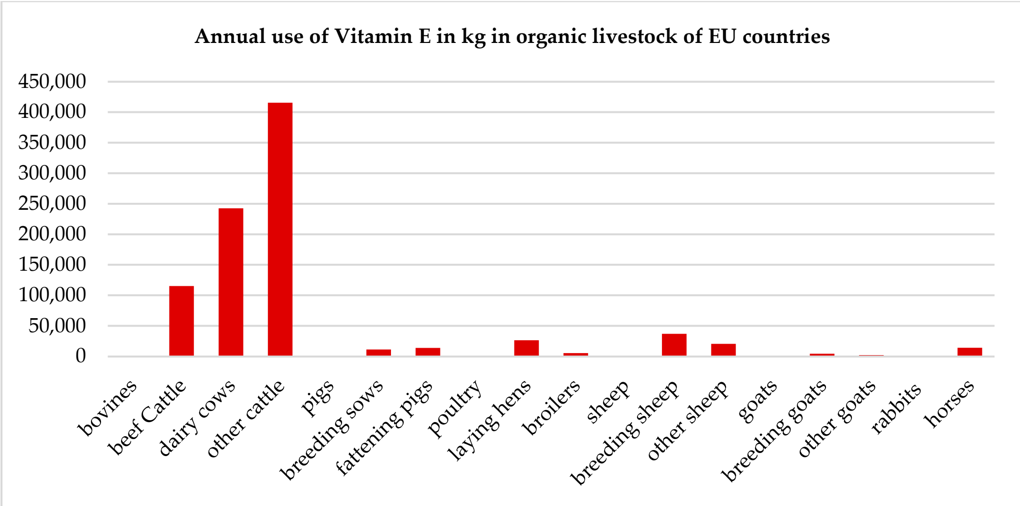

Figure 5. Annual use of vitamin E in organic livestock species in EU countries.

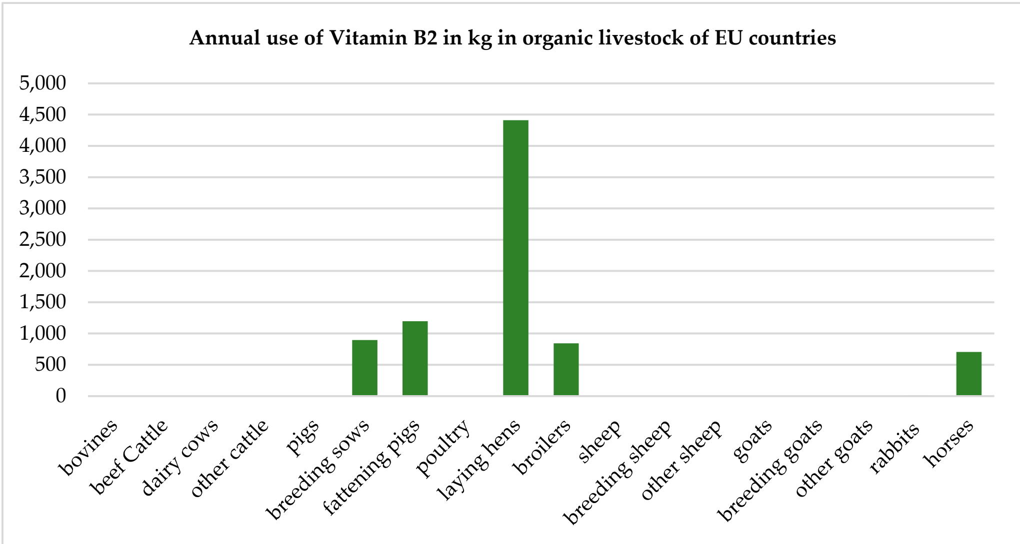

Figure 6. Annual use of vitamin B2 in organic livestock species in EU countries.

Any reduction in use for the reasons of synthetic origin and solvents (lipophilic vitamins) or shortage of GMO-free production (B vitamins) needs specific scientific background which would allow alternative supplementation or changing sources without risking problems with animal health and welfare. Here, a clear lack of data was identified which needs to be experimentally produced in the future. This has been started in the case of vitamin B2 in poultry [55,95].

The specific situation for lipophilic vitamins on one hand, and B vitamins on the other, can be illustrated with the examples of vitamin E and vitamin B2. Vitamin E availability from fresh grass is much higher than from cereals or maize silage, which is why supplements to grazing animals, as is common in organic dairy and beef production, could be lower than the international recommendation, which is based on intensive diets rich in cereals and maize [96]. So far only one European feeding system for cattle—the French—acknowledges the influence of grass vs. concentrates [97]. In order to avoid a lack of vitamin E in organic herds during winter feeding [98], such differentiated recommendations, which consider not only the animals' needs but also the varying provision by different feeds, urgently need to be developed.

Riboflavin (vitamin B2) deficiency occurs for instance in livestock birds, especially in growing chicks and broilers, and symptoms are severe and relevant to health and welfare [39]. Therefore, non-supply is no option. However, since the GMO-free production is expensive to a relevant degree, mitigation of supplements is desirable. Based on current experimental work [39,55,95] it appears to be safe to reduce riboflavin supplements to poultry by approximately 30–50% compared to FEFANA recommendations. The safe levels depend on the animal category; sufficient supplements are especially essential for parent animals and chicks. As for vitamin E in cattle and for riboflavin in poultry, the provision of the vitamin with the basic feed formulation is relevant, and legume seeds as well as silages can significantly contribute as natural sources [99]. Since animal welfare is concerned, the indicated options need careful experimental backgrounding, though.

3.6. Available Policy Instruments and Voluntary Initiatives to Reduce the Use of Contentious Inputs in Organic Production in the EU

The total number of replies to our survey on policy instruments was 255 (from 69 respondents), of which 53 contained details of contentious input-reduction initiatives (copper: 18 (34%), mineral oil: 4 (8%), vitamin: 3 (6%), anthelmintics: 10 (19%), antibiotics: 11 (21%), external nutrient inputs: 7 (13%)). A total of 29 (55%) entered initiatives were related to crop production topics (copper, mineral oils, external nutrient inputs), and 24 (45%) to animal husbandry topics (vitamins, anthelmintics or antibiotics). The geographic scope of the entered initiatives was mainly national (44% (10) of copper, 100% (4) of mineral oils, 67% (2) of vitamins, and 50% (5) of anthelmintics, 64% (7) of antibiotics and 57% (4) of external nutrient inputs). The nature of initiatives was mostly public (68%, 36 out of 56) in all six investigated topics. Need for declaration/justification of use and voluntary reduction were the most frequent type of instrument in the survey (19% and 23% of all six topics together, respectively). The expert evaluation of the success of the initiatives was most often (76%, 39 out of 51) between 3 and 4 on a scale from 1 to 5, where 1 was the worst and 5 was the best rating. Experts were thus generally neutral or positive towards the reported initiatives. No initiative received 1 as a rating. (Results are summarized in Figure 7).

A list with the description of reported policy instruments and voluntary initiatives by country was developed based on the responses presented in Appendix F. After reviewing the entries and eliminating duplicates 32 initiatives were identified. Most replies for all topics were received from Western Europe (63%, $n = 20$), while 37% of replies came from Central–Eastern Europe (19%, $n = 6$), Northern Europe (12%, $n = 4$) and Southern Europe (6%, $n = 2$). According to the type of the tool (voluntary initiative, policy instrument, project or product) we found that the majority (56%, $n = 18$) of the responses fall under the category of voluntary initiative, followed by 22% (7) project, 16% (5) policy instrument and 6% (2) product categories. A high number 34% (11) of the total initiatives, (61% of the voluntary initiatives), are related to additional labels, having stricter measures than established in the EU organic directives. A significant number (25%, $n = 8$) of collaborative initiatives were submitted. These are joint efforts of several Non-Governmental Organizations (NGOs), industry or administrative agencies, aiming to raise awareness of different contentious inputs and provide farmers with best practices to reduce their usage. 56% (18) of the reported initiatives are related to certified organic production, while 44% (14) are targeting the whole agricultural sector.

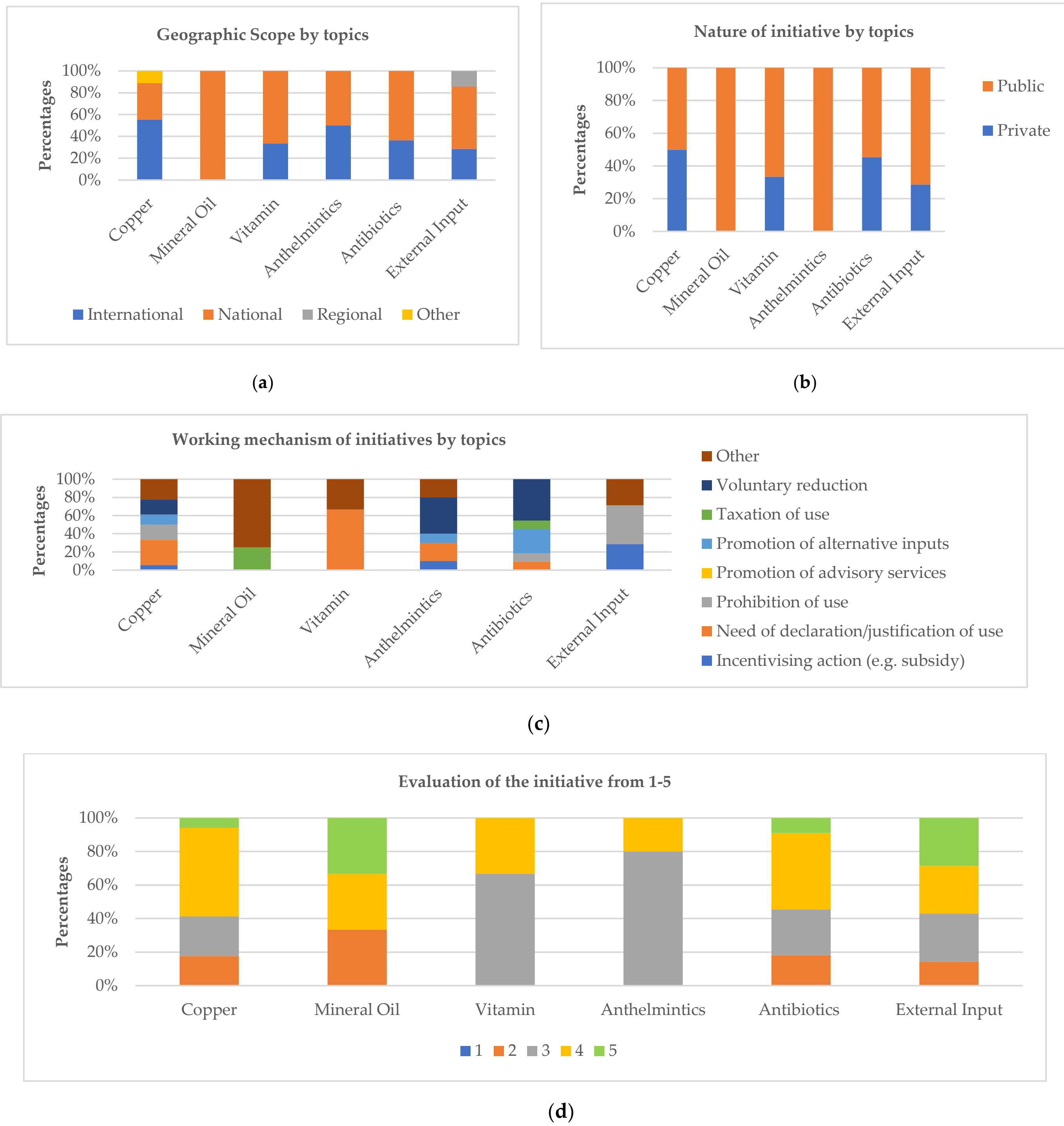

Figure 7. Proportion of policy tools and initiatives of the six input categories based on geographic scope (**a**), nature of the initiative (**b**), mechanism of the initiative (**c**) and individual evaluation from 1–5 (**d**).

4. Discussion

Based on the results of the six RELACS reports, it is evident that the six categories of investigated contentious inputs see widespread use among organic farmers in many of the surveyed countries, while the availability or the uptake of alternative products, preventive strategies or treatments is rather scarce. Results differ between countries, which is surely due to the differences in cultivated crops (e.g., horticultural vs. arable crops) and applied systems (e.g., greenhouse vs. open-field production), but may also be related to the historic presence of organic farming and the already existing policy measures and voluntary initiatives aiming to achieve reduction targets. One of the greatest limitations faced in estimating organic input usage was the absence of a centralized database, i.e., an inventory and continuous monitoring of permitted usage, dosage of PPPs such as copper and mineral oils, as well as treatments such as anthelmintics, antibiotics and vitamins per country at the EU scale. Therefore, the results presented in this paper only reflect a fraction of the EU-wide reality of input usage in organics and rely mostly on expert knowledge. A centralized database would offer closer monitoring in the future, potential surveillance of drug resistance, and an improved system to benchmark future reductions in contentious inputs' use.

Altogether, copper usage is most problematic in grape and olive production as its application in these crops is very close to legal limits. It is evaluated around 3100 t/year in the 12 survey countries, which means that for these countries, crops alternative PPPs would need to be supplied annually in a quantity large enough to equal the effect of this much copper to serve the needs of their organic production. This poses a quantitative obstacle for copper substitution, and a clear target to aim for. However, it is worth to note that already existing strategies that aim for copper reduction such as forecast-based spraying can greatly contribute to the reduction efforts. Experts could not provide a similar estimation for mineral oil use. Therefore, further calculations and deeper research is necessary to draw conclusions on the actual input usage in the whole EU, and the amounts needed of potential alternatives. In addition, copper and mineral oil replacement with alternative products at present seems to be a difficult undertaking in light of the lack of products available on the market which have a similar range of application purposes and efficacy, while having a competitive pricing. However, there are promising products in the pipeline such as citrus essential oils [100,101], or *Clitoria termatea* oil [102,103]. The development and registration of such alternatives is financially challenging, as is the upscaling of their raw material supply and product manufacturing [104], especially considering the estimated amounts needed to replace copper and mineral oils. That is why already existing and future reduction policies and voluntary initiatives are essential to support replacement efforts. Besides the international Demeter standard applied by biodynamic farms, and the BioSuisse standard, Germany developed a strategy with the aim to find alternatives to copper with the help of innovative approaches from research and practice and to further reduce its use [105].Whereas, in the Central–Eastern European region, in the absence of relevant public policy targets (in many countries reduction policies are only recommendations without any enforcement or monitoring), voluntary private initiatives took the lead in decreasing contentious input usage, but their efficacy is currently not measured. Altogether, it seems that in order to reach the targets of the Farm to Fork strategy and the Organic Action Plan, well-focused EU and national-level policy instruments are necessary, while private voluntary initiatives should be supported through widespread information sharing and promotion efforts.

The main issue with mineral oil use, besides the absence of a centralized database, is that, contrary to copper, its maximum usage/concentration is not regulated in any way by the EC Regulation 889/2008 [5]. This contributes to the tendency observed during the data collection that reduction efforts are perceived as less important by the actors in organic farming compared to copper or external nutrients. A similar tendency was observed in case of anthelmintics reduction compared to antibiotics reduction—the latter being perceived more important. Mineral oil and anthelmintics reduction efforts are further hindered by the fact that these contentious inputs are neither recognized nor addressed in the Farm to Fork strategy or in the Organic Action Plan [3], which does not strengthen the awareness raising and related national-level policy developments.

As for the external nutrient input usage, results showed that the majority of surveyed farms had a positive N budget, while for K and P, on average they had slight deficits, although on some farms deficits were pronounced and a risk of soil mining was identified. In a study analysing the German farms [106] authors found that reliance on biological nitrogen fixation depletes soil phosphorus and potassium reserves. Furthermore, soils were collected from all the German farms and a decrease in extractable soil P was detected from soils with a prolonged history of organic farming, indicating a long-term risk of soil P mining in organic farming systems. An unbalanced supply of P-rich external inputs (too much or not applied at all) was observed on a number of the surveyed farms. This issue was recognized by several studies carried out by Möller and Cooper et al. [107,108].

Expert input from the respective countries generally aligned with the trends observable in the collected data. Regarding the sustainability of nutrient supply, a synthesis of expert opinion identified key areas of concern. The first is that there is an undersupply of external fertilizer inputs that are permitted in organic systems, particularly for stockless holdings. Manure is (for many farms) not easy to source and high application rates of lower quality compost can cause problems with high levels of P and K. Input of nutrients to organic arable farms is necessary to maintain yield levels on farms with little or no livestock. Secondly, the purchase of external inputs to balance nutrient needs is costly for farmers, and farmers therefore rely strongly on ensuring a sufficient number of legumes in the rotation to meet soil fertility needs (for N). However, focusing on ensuring a sufficient N supply can cause P and K deficiencies which, if not addressed, will slowly become problematic for producers. Thirdly, the quest for reliable supplies of organic sources of sufficient nitrogen and other limiting nutrients (e.g., from composts, vinasse, seaweed or digestates) is fraught with difficulty because these sources are highly variable (regarding nutrient content), and are difficult to manage, as their effect on soil function and nutrient release processes is hard to predict or standardize.

Various experts discussed the concept and their understanding of the term 'contentious inputs'. Some experts based their opinion on definitions offered by regulations (which for many were perceived as imprecise), whilst others questioned the sustainability of excluding certain input types (for example non-organic manures from extensive production systems), referring to the organic principles of recycling. Experts expressed differentiated views of reliance, often contingent on location and system types. The use of contentious inputs is predicated by several factors influencing the sourcing and usage of conventional manures: limited availability, the high price of application, and farmers' principles. Furthermore, reliance of arable farms on conventional sources can be high in some countries as it is difficult to source organic manure. Reliance in horticulture is quite high, due to the nutrient requirements in intensive systems, but sometimes price and availability limit use. A general view is that the main contentious input in the organic sector by far is conventional manure, particularly pig and cattle slurry, as well as chicken manure pellets. The use of commercial chicken manure pellets is gaining popularity in some countries, due to convenience of use, and the source of such inputs is not always clear. Finally, a strong view, particularly from those involved in regulation, was that there is a clear need to more explicitly describe what 'industrial farming' refers to in the legislation.

In a recent study by Quemada et al. [109] exploring nitrogen indicators of conventional farm performance among farm types across several European case studies, average N outputs of approximately 100 kg N ha^{-1} were reported for arable and pig farms, 140 kg N ha^{-1} for mixed pig farms, 75 kg N ha^{-1} for mixed dairy farms and 65 kg N ha^{-1} for dairy farms. The study represented 1240 farms from Atlantic-, Continental- and Mediterranean Europe. Considering that yield levels in organic agriculture are often assumed to be around 75 % of the level found in conventional agriculture, the yields found in Denmark, Switzerland and North Germany are generally in line with the findings of Quemada et al., while the overall N outputs are rather low, given that in our study mainly arable or mixed farms with a low to zero animal density were selected. Thus, farms relying less on external input and more on BNF, generally have a lower output of N and thus a lower land-use efficiency.

It is thus important to relate the level of desired intensification on farms with the needs for external nutrient inputs. The results of our study indicate that if access to external nutrient supply would diminish as a result of future regulation (for example of 'contentious inputs'), so would the outputs from the more intensively managed farms (e.g., in North

Germany, Switzerland and Denmark). IFOAM's organic vision for Europe 2030 includes "providing flavourful and abundant food to contribute to the welfare of our planet and the quality of life of all people" [110] (p. 7). Therefore, land-use efficiency and intensification levels need to be carefully considered in future development of the regulation, if organic food is to be readily available for the EU population. There is already an undersupply of nutrients across the EU to stockless arable farms and farms with few animals, and this will only become more pressing with time, as the Farm to Fork strategy is implemented, unless substantial development occurs in both accessibility and acceptability of societal and industrial resources.

For anthelmintics and antibiotics, extrapolated estimates on their input usage in organic systems in Europe were calculated. We are confident in these estimates, as they are in agreement with previous data where organic farmers were surveyed. Nevertheless, it became evident that organic control bodies should probably fill the void created by the lack of centralized databases through accessing and monitoring veterinary data on treatments and recording usage. The electronic medicine book initiative in the UK is a good example of how systematic data collection can be performed. Our survey data showed that there are huge differences between countries in the anticipated risk of diseases, as indicated by the percentage of farmers including the medicines in their health plans. It is important to emphasize that high or low proportions of farmers requesting anthelmintic and antibiotic use in their health plan or supplementary, may reflect differences in the prevalence/risk of infections but may also be associated with differences in the regulation of these drugs in the different countries. In addition, antibiotics must be prescribed to treat individuals, therefore, it is difficult to predict infection levels and to request the drugs as part of health plans. Countries such as Lithuania, the Czech Republic, or Poland, with relatively small proportions of farmers using allopathic medicines, may have lower disease threat, higher treatment threshold or good preventive strategies for disease control. Further investigation is required to identify the drivers of allopathic medicines use in these countries, which may also benefit other parts of the world.

Although UK farmers appear, in general, to be open to alternative therapies in case of anthelmintics, the current uptake is low. These results are in agreement with recently published data from the PrOPara project which surveyed the anthelmintics usage of organic farms in eight countries where beef farmers were rather dismissive of any alternative measures due to a lack of perceived risk of future anthelmintics resistance, denial of any production loss and unwillingness to have additional costs of new control strategies [111].

The case of vitamin supply to livestock shows that the field of micronutrients in organic animal feeding is little developed and supplementation levels rely on the large body of conventional feeding systems, such as of national institutions (e.g., INRAe) [97] or international industry associations (FEFANA) [90]. As long as no specific data for organic feeding concepts exist, there is no alternative to using conventional recommendations, in order to avoid harm to animal health and welfare. However, as lipophilic vitamins are often of synthetic origin and B vitamins need expensive non-GMO production strains, revision of vitamin requirements for organic feed formulations, also considering specific feed components, housing conditions and genotype backgrounds appears necessary. The development of alternatives, such as European production strains for GMO-free B-vitamins [39] or the dedicated use of feed components intrinsically containing particularly high concentrations of target vitamins [98,99], must be an essential part of improving the knowledge about vitamin usage in organic livestock. The target stakeholders for these aims are feed and premix producers, as well as veterinarians, and, regarding feedstuff intrinsic vitamins, farmers are also concerned. The research work ahead in order to produce comprehensive data on vitamin and mineral requirements of organic livestock is large and challenging. The survey on policy instruments only showed one voluntary initiative toward the reduction in synthetic sources of vitamins: the Soil Association's own private standard by which synthetic vitamins are regulated in animal feed [112].

The policy survey showed that most of the initiatives that have been established to reduce the use of continuous inputs in organic systems are voluntary or project-related and only a few of them are policy instruments introduced by public authorities. Three out of four of such public initiatives are lacking proper implementation according to respondents. Besides restrictions, organic agriculture needs reliable alternatives to contentious inputs, but they are scarcely available. To tackle these shortcomings and to support the sector, there is a need for better dissemination of available alternatives, which are in line with the organic principles, as well as more research to find additional suitable replacement materials and strategies. For this, the Commission will allocate funding under Horizon Europe for research and innovation projects that aim to find alternative approaches and replacements to contentious inputs and on alternative sources of organic vitamins from 2022, and it will promote the use of alternative plant protection products through farm advisory services [3]. Another constraint is the scalability of possible alternatives. Contentious inputs are currently used in such large amounts that it will be difficult to produce similar quantities of alternatives. The cooperation between the organic and conventional sectors in the UK, such as the Alliance to Save our Antibiotics [113] or the Responsible Use of Medicines in Agriculture (RUMA) Alliance [114] in order to reduce antibiotic and anthelmintic usage, might be a good example for the organic sector of how awareness-raising, dissemination of best practices and systematic data collection can support transition and reaching sustainability goals.

5. Conclusions

It can be highlighted that research is underway to map and assess the current use of contentious inputs in organic farming in order to inform relevant EU and national policy makers with tailored recommendations. However, this is barely enough at the moment, as significantly more research and policy support are needed in the near future to achieve the prerequisites for the targeted 25% share of organic farmland by 2030 in the EU. More in-depth, EU-wide, multi-actor projects focussed on reducing contentious inputs need to be launched. Better data collection, the development of relevant databases on the use of inputs and extensive knowledge sharing and awareness raising on existing alternatives need to be established among agroecological, organic and non-organic farmers in Europe. In addition, the communication and support of already existing good practices is paramount to upscale similar activities in countries where reduction efforts are not yet recognized by national policies or by private initiatives. Cooperation among the value chain actors in the organic sector and with conventional stakeholders need to be incentivized, e.g., through creating a market for alternative replacement products and strategies that encourages private investment. Moreover, better and harmonized regulation of input use is necessary to enable the entry of new alternative products into the market. At the same time, the solution should not only be sought in replacement products, but also in the application and spread of agroecological practices targeting contentious input use among the farmers.

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Appendix A. In-County Interview Questions for Quantifying Inputs and Outputs of Case Study Farms for the External Nutrient Inputs' Use

1. Basic Information
Name of facilitator
Date
Name of interviewee
Farm address (including country)
Phone No.
E-mail address (if applicable)
Date farm converted to organic farming
Note to enumerator: Data period is for three years. We want to collect input and output data for harvest years: 2017, 2016 and 2015. For example, any inputs for the 2017 harvest year are noted as 2017. Focus nutrients are NPK. Focus on in and out flows.
2. Cropping history (including legumes and catch crops) and livestock held for the farm:
2.1 Cropping season
2.2. Crop
2.3. Total Area for crop (ha)
2.4. Livestock (please note type and number for each year
3. Please specify all input types used on your farm and sources over the past three cropping seasons (2015, 2016 and 2017). Note, only inputs sourced from outside the farm boundary. Please provide as much detail as possible about where the input was received from (source) and note if organic or not-organic farm source (if sourced from a farm). The amount refers to the total input for the given year for the whole farm.
3.1. Year
3.2. Type
3.3. Amount (kg)
3.4. Source
3.5. Distance (km)
3.6. Method of application
The next question requires information about outputs, i.e., what was sold/removed from the farm for each of the past three reporting years ie 2015, 2016 and 2017. Please add amounts in the relevant columns. Please record harvested amount.
4. Farm Outputs grains and grain legumes (in t/ha or kg/ha between 2015–2017)
4.1.Wheat, barley, rye, oats, corn, triticale, spelt, other
5. Farm Outputs root crops, vegetables and others (in t/ha or kg/ha between 2015–2017)
5.1. Potatoes, sugar beet, carrots, others
6. Farm Outputs animal products and feed
6.1. Milk (litres), Meat (Kg DW) or (Kg LW), Eggs (No.), Manure/slurry
(tonnes) with approximate DM content, others
7. Why did you choose organic farming? Please score the following potential advantages of farming organically, from 1–5, where 1 is not important, 2 is slightly important, 3 is moderately important, 4 is important and 5 is very important

- Higher price for output
- Higher yield
- Better market
- Health benefits
- Reduces input costs
- Improves soil fertility
- Environmental benefits

- Better Quality
- Other, please specify

7. Please score the following possible problems encountered when farming organically, from 1–5, where 1 is not important, 2 is slightly important, 3 is moderately important, 4 is important and 5 is very important

- Not enough manure
- Pest control
- Low yield
- Lower quality
- Weed control
- Lack of labour
- Problem with price
- Disease control
- Other, please specify

8. Have there been any unusual problems (drought, lack of market, diseases, pests . . .) with in the cropping seasons of 2015–2017? (Please state kind of problem and cropping season.)
2015:
2016:
2017:
9. In what ways has you overall farm nutrient management changed since you converted to organic farming in regard to nutrient management? Please describe how
10. Do you think that you apply sufficient amount of fertilizer to your crops? Please explain [Note: please get the farmer to elaborate on why they answered as they did]
11. Does your farms rely on external inputs to fulfil the nutritional need?
Yes/No
12. Do you think you can estimate your nutrient farm gate balance is for the following nutrients? Please answer in kg per ha and year.
N:
K:
P:
13. What is the main reason for the use of external inputs?
Fulfilling nutrient needs of:
N
P
K
S
Humus
Others (specify)
14. Looking to the future, what do you think the main sources of nutrient inputs to your farm will be? Please explain:
15. Where do you get advice from about how to manage nutrients on your organic farm? [Note: Please elicit as detailed information from the farmer as possible, including names of advisors (if the farmer is willing to share)]
16. View on recycling nutrients from organic waste streams: Please try to answer without regarding the current legislation on the use of recycled fertilizers!
(a) In general, would you consider using recycled fertilizer on your farm?
Yes/No
(b) Please fill in the table below about which recycled fertilizer you would consider using and which not. Please select a reason behind your decision.
Household sourced waste
Garden and park waste
Digestibles (Biogas)

Compost
Sewage sludge
Sewage sludge products (struvite, ashes . . .)
Bone/meat meal and similar others
17. Are there any analysis results from soil samples? (possibly copies of reports/scanned reports) for the farm?

Appendix B. Survey Questions for Identifying Mineral Oil Use in Partner Countries

1. What are the Paraffin oil active substances (Paraffin oil and white mineral oil) which are authorized in your country?
2. In which context are they used in your country?
Crops
Commercial name
Pests controlled
Formulation
Concentration Used g/L
Number & applications period
Application rate/treatment
3. Are there any registered alternatives to the use of Paraffin oil in your country?

Appendix C. Survey Questions for Identifying Copper Use in Partner Countries

Please fill in the following with your country data on copper use in almond, apple, apricot, avocados, bananas, barley, beans berries, no details/n.e.c. berries, other, black chokeberries blackberries, blueberries, brassicas, buckthorn, buckwheat, cherries, chestnuts, cotton, currants, dates, figs, flax, fodder beet, fruit temperate, no details, fruit, temperate, other, fruit, tropical and subtropical, no details, fruit, tropical and subtropical, other, grain maize and corn cob mix, grapefruit/pomelos, grapes, no details grapes, raisins, grapes, table, grapes, wine, hazelnuts, hemp, hops, industrial crops, no details, industrial crops, other, kiwis, lemons and limes, lentils, linseed (oil flax), lupine, nectarines, nuts, no details, nuts, other, oats, oilseeds, no details, oilseeds, other, n.e.c, olives, no details, olives, oil, oranges, other cereals n.e.c., other fodder roots, peaches, peaches and nectarines, no details, pears, peas, pistachios, plums, pome fruit, no details, pome fruit, other, pomegranate, potatoes, protein crops, no details, protein crops, other, pulses, pumpkin seeds, quinces, rape and turnip rape, raspberries, rice, root crops, no details, root crops, other, n.e.c, rye, soybeans, spelt, stone fruit, no details, stone fruit, other, strawberries, sugar beet, sugarcane, sunflower seed, tangerine tea, textile crops, no details, textile crops, other, n.e.c., tobacco, triticale, vegetables, fruit, vegetables, leafy or stalked, vegetables, broccoli, vegetables, no details, vegetables, other, vegetables, root tuber and bulb, walnuts, with shell, wheat, greenhouse tomato, greenhouse cucumber, greenhouse other, greenhouse ornamentals, outdoors ornamentals

(a) Organic area [ha]:
(b) Organic area share [%]:
(c) EPPO Codes of diseases:
(d) PPP authorization of copper (kg/ha)
(e) PPP authorization of copper in organic farms (kg/ha)
(f) PPP limits of copper by farmers associations (active substances, kg/ha)
(g) Estimated PPP use of copper in organic farms (kg/ha)
(h) Estimated fertilizer use of copper (kg/ha)
(i) Estimated fertilizer use of copper in organic farms (kg/ha)
(j) Alternative products in organic farms (active substance, kg/ha)

Appendix D. Survey Questions for Identifying Anthelmintics and Antibiotics Use in Partner Countries

1. What percentage of organic farms that you have inspected over the past twelve months have Anthelmintics as part of their health plan?
2. How confident are you that your answer to Q1 is accurate?
3. What percentage of organic farms that you inspect have requested to use Anthelmintics outside of their health plan in the past twelve months?
4. How confident are you that your answer to Q3 is accurate?
5. What percentage of organic farms that you have inspected over the past twelve months have Antimicrobials as part of their health plan?
6. How confident are you that your answer to Q5 is accurate?
7. What percentage of organic farms that you inspect have requested to use Antimicrobials outside of their health plan in the past twelve months?
8. How confident are you that your answer to Q7 is accurate?
9. How many organic farms have you inspected in the past 12 months?
10. Which country are you working in?

Appendix E. Survey Questions for Identifying Existing Policy Instruments and Voluntary Initiative to Reduce the Use of External Inputs in Organic Farming

Description: This survey was prepared in frame of the RELACS 'Replacement of Contentious Inputs in Organic Farming Systems' Horizon 2020 project and aims to collect past and contemporary public and private initiatives for the reduction of contentious input usage in organic farming in the RELACS project partner countries, and beyond. Based on the survey results, an inventory of available international/national/regional policy instruments such as incentivization, taxation, support for advisory services, or prohibition will be compiled and published as a guiding document for policymakers. Thank you in advance for your valuable cooperation!
This survey takes approximately 10–20 min to complete.
The survey will be open until: 19 March 2021
1. Identification of the Responder (please provide contact details for further possible inquiry about your examples. Your data will not be shared with any third party, and will be only used for the purpose of this survey)
1.1 Name:
1.2. Institute:
1.3. Country:
1.4. Email address
2. Are you aware of any existing past or contemporary activities/initiatives/certification which directs/incentivizes farmers towards copper/mineral oil/external nutrient input/ anthelmintics/antibiotics/vitamin usage reduction in your country? Y/N *
2.1. Please write the name of the initiative here: _______________
2.2. Please chose the geographic scope of the initiative:

- international
- national
- regional
- local

2.3. Please chose the nature of the initiative:

- public
- private

2.4. Please choose the main working mechanism of this initiative:

- incentivizing action (e.g., subsidy)
- prohibition of use
- taxation of use
- need of declaration/justification of use

- promotion of alternative inputs
- promotion of advisory services
- voluntary reduction
- other: . . .

2.5. Please describe this initiative in a couple of sentences (e.g., when was is launched, what are its expected/achieved results, is it still active etc.)
2.6. Please provide a website link or other reference to this initiative, if available
2.7. Based on your experience, does this initiative work well? (1 = not at all, 5 = perfectly effective)
2.8. If you are not fully satisfied with the implementation of the initiative, please specify how it could be more efficient.
2.9. If you have further policy examples to share on copper/mineral oil/external nutrient input/anthelmintics/antibiotics/vitamin usage reduction, please continue here

Appendix F. Result of the International Survey to Map Existing Policy Tools and Voluntary, Public/Private Initiatives for the Reduction of Contentious Input Use in Organics in the EU

Table A1. List and description of existing tools (policy instruments, voluntary initiatives, projects and products) in the six input categories, ordered by satisfaction level, evaluated by the responder.

Copper							
Initiative	**Satisfaction Level [1–5]**	**Tool**	**Geographical Coverage**	**Nature**	**Mechanism**	**Description**	**Responder Country**
Demeter certification	4	Voluntary initiative	International	Private	Voluntary reduction	No copper is permitted in Demeter vegetable production. For permanent crops an average of 3 kg of copper/hectare/year is allowed. https://www.demeter.net/certification/standards (accessed on 30 March 2021).	DE, IT
Biosuisse certification	4	Voluntary initiative	International	Private	Voluntary reduction	Limited copper usage/ha/year: vegetables, potatoes, wine, hops. The limit for stone fruit is 4 kg, for soft fruit 2 kg, for pome fruit 1.5 kg. https://www.bio-suisse.ch/en/Import_requirements.php (accessed on 30 March 2021).	HU
Naturland certification	4	Voluntary initiative	International	Private	Voluntary reduction	Limited copper usage/ha/year. https://www.naturland.de/images/UK/Naturland/Naturland_Standards/Standards_Producers/Naturland-Standards-on-Production.pdf (accessed on 30 March 2021).	HU
Bio Austria certification	4	Voluntary initiative	International	Private	Voluntary reduction	Limited copper usage/ha/year. For arable crops 2 kg, for fruits and grape 3 kg, for hops 4 kg. https://www.bio-austria.at/app/uploads/2015/05/BIO-AUSTRIA-Produktionsrichtlinien-202004.pdf (accessed on 30 March 2021).	HU
Resistance breeding	4	Project	International	Public	Promotion of alternative inputs	Breeding for resistance in case of potato, wheat, soybean and buckwheat. www.ecobreed.eu (accessed on 30 March 2021).	DE

Table A1. *Cont.*

Soil Association Standards	4	Voluntary initiative	National	Private	Need of declaration/justification of use	Restrictions on upper levels on permitted usage within organic standards. Recent developments in copper usage regulations in potatoes mean the standard could become obsolete—copper is no longer permitted in organic potato production in the UK. https://www.soilassociation.org/our-standards/ (accessed on 27 March 2021).	UK
German Copper Minimisation Strategy	3	Policy instrument	National	Private	Voluntary reduction	The strategy lists relevant measures in different crops, which would hopefully lead towards copper minimization. Originally it was both for organic and conventional farming, currently only organic seems to be actively involved. https://kupfer.julius-kuehn.de/index.php?menuid=29 (accessed on 30 March 2021).	DE
Promotion of the Vitisan SP by the Biocont Hungary	3	Product	National	Private	Promotion of alternative inputs	Promotion of an available alternative PPP against apple scab. https://biocontmagyarorszag.hu/ (accessed on 27 March 2021).	HU
Estonian Action Plan for the Sustainable Use of PPP's	2	Policy instrument	National	Public	Voluntary reduction	Emphasises the sustainable use of PPPs, implementing IPP, raising awareness. No specific measures connected to copper or PPP usage in organic farming. https://www.agri.ee/sites/default/files/content/arengukavad/tegevuskava-taimekaitsevahendid-2019-eng.pdf (accessed on 27 March 2021).	EE
IFOAM OE Copper minimisation strategy		Voluntary initiative	International	Private	Voluntary reduction	Launched in 2018—brought together a number of national initiatives. https://www.organicseurope.bio/content/uploads/2020/10/ifoam_eu_copper_minimisation_in_organic_farming_may2018_0.pdf?dd (accessed on 30 March 2021).	DE
			Mineral oil				
Initiative	**Satisfaction level** [1–5]	**Tool**	**Geografical coverage**	**Nature**	**Mechanism**	**Description**	**Responder country**
Sunflower oil based PPP's	5	Product	International	Public	Available cheap alternative products on the market	Vegarep EC https://bvn.hu/products/vegarep-ec/ (accessed on 28 March 2021).	HU
Estonian Action Plan for the Sustainable Use of PPP's	2	Policy instrument	National	Public	Voluntary reduction	Stresses the sustainable use of PPPs, implementing IPP, raising awareness. No specific measures connected to copper or PPP usage in organic farming. https://www.agri.ee/sites/default/files/content/arengukavad/tegevuskava-taimekaitsevahendid-2019-eng.pdf (accessed on 28 March 2021).	EE
			Vitamin				
Initiative	**Satisfaction level** [1–5]	**Tool**	**Geografical coverage**	**Nature**	**Mechanism**	**Description**	**Responder country**
Soil Association Standards	4	Voluntary initiative	International	Private	Need of declaration/justification of use	Synthetic vitamins are regulated in animal feed. https://www.soilassociation.org/our-standards/ (accessed on 30 March 2021).	UK

Table A1. *Cont.*

NATVIT project—Natural sources of antioxidants—a necessity for animal health and welfare and product quality in organic livestock production	3	Project	National	Public	Research	A research project from 2009 to 2012, aims to replace synthetic antioxidants (vitamins) with natural sources in feed supplements. https://www.nibio.no/en/projects/natvit.natural-sources-of-antioxidants-a-necessity-for-animal-health-and-welfare-and-product-quality-in-organic-livestock-production (accessed on 30 March 2021).	NO
				Anthelmintics			
Initiative	**Satisfaction level** [1–5]	**Tool**	**Geografical coverage**	**Nature**	**Mechanism**	**Description**	**Responder country**
RELACS—Alternatives to Anthelmintics—Natural methods of worm control in sheep	4	Project	International	Public	Promotion of alternative inputs	Natural methods of worm control in sheep: e.g., grazing on heather and introduction of naturally occurring fungi (*Duddingtonia flagrans*) to feed. https://www.soilassociation.org/our-work-in-scotland/scotland-farming-programmes/resources-for-farmers/alternatives-to-anthelmintics/ (accessed on 27 March 2021).	UK
AHDB—Better Returns Programme	3	Voluntary initiative	National	Public	Voluntary reduction	The initiative provides technical guidance documents, webinars and demonstration farms in order to disseminate best practices. https://ahdb.org.uk/knowledge-library/worm-control-in-sheep-for-better-returns (accessed on 27 March 2021).	UK
COMBAR an EU COST action on the advancement of work on anthelmintic resistance	3	Project	International	Public	Improve diagnostics to identify resistance to anthelmintics and revise drug use	COMBAR, in order to tackle anthelmintic resistance, integrates novel developments in the field of diagnostic tests; vaccines to protect animals from infection; anti-parasitic forages, selective treatment strategies and decision support tools. https://www.combar-ca.eu/ (accessed on 27 March 2021).	UK
COWS—Control Of Worms Sustainably	3	Voluntary initiative	National	Public	Voluntary reduction	Control Of Worms Sustainably (COWS) is a voluntary initiative aiming to provide the best available, evidence-based information to the beef and dairy cattle industries in relation to the sustainable control of both internal and external parasites. https://www.cattleparasites.org.uk/ (accessed on 27 March 2021).	UK
SCOPS	3	Voluntary initiative	National	Public	Voluntary reduction	SCOPS is an industry led group that works in the interest of the UK sheep industry. It recognises that, left unchecked, anthelmintic resistance is one of the biggest challenges to the future health and profitability of the sector. SCOPS supports farmers with information on parasite lifecycle, advice on best times to intervene and provision of information on the damage caused by over and misuse. https://www.scops.org.uk/ (accessed on 27 March 2021).	UK

Table A1. *Cont.*

Antibiotics							
Initiative	**Satisfaction level [1–5]**	**Tool**	**Geografical coverage**	**Nature**	**Mechanism**	**Description**	**Responder country**
Bonafarm control on antibiotics use	5	Voluntary initiative	International	Private	Voluntary reduction	Bonafarm group, the largest pig producer in Hungary has a strategy to control the use of antibiotics on some farms there is no antibiotics usage during the fattening phase. The products are certified and labelled. https://pick.hu/hu/premium/ (accessed on 30 March 2021).	HU
Responsible Use of Medicines in Agriculture (RUMA) Alliance	4	Voluntary initiative	National	Public	Voluntary reduction	RUMA is an independent non-profit group, involving organisations that represent all stages of the food chain from 'farm to fork', to produce a coordinated and integrated approach to best practice in animal medicine use and promote the highest standards of food safety, animal health and animal welfare in the https://www.ruma.org.uk/ (accessed on 30 March 2021). British livestock industry. RUMA set UK antibiotic reduction targets https://www.ruma.org.uk/targets-task-force-2021-2024/targets-2017-2020/ (accessed on 30 March 2021).	UK
RELACS—Mastitis Trial using essential oils	4	Project	National	Private	Promotion of alternative inputs	The trial aims to alleviate the use of antibiotics in the treatment of mastitis in cow herds by use of alternatives such as essential oils and farmer field schools (where farmers meet to exchange ideas not only relating to the trial subject). https://www.soilassociation.org/farmers-growers/farming-news/2019/january/14/reducing-antibiotics-in-dairy-farming/ (accessed on 30 March 2021).	UK
Soil Association Higher Standards	4	Voluntary initiative	International	Private	Prohibition of use	Soil Association require higher standards in it's organic certification scheme that further limits the use of certain antibiotics. The use of colistin is prohibited in any case. The use of critically important antibiotics is restricted, they are allowed only when no other treatment would be effective. https://www.soilassociation.org/our-standards/read-our-organic-standards/farming-growing-standards/ (accessed on 30 March 2021).	UK
AHDB led e-medicine books for collecting standardized antibiotic data	4	Project	National	Public	Voluntary reduction	Development of online e-medicine books with standardized methods for antibiotic data collection and report https://ahdb.org.uk/electronic-medicine-book-for-pigs-emb-pigs, https://ahdb.org.uk/medicine-hub (accessed on 30 March 2021).	UK

Table A1. *Cont.*

Association of Classical Homeopaths of Germany (VKHD): Use of homeopathics	3	Voluntary initiative	National	Private/public	Promotion of alternative inputs	Dissemination and educational programme about the use of homeopathics. https://www.landwirtschaftskammer.de/landwirtschaft/weiterbildung/2021-02-02-homoeop-rind.htm (accessed on 30 March 2021).	DE
Alliance to save our Antibiotics	3	Voluntary initiative	National	Public	Promotion of alternative inputs	The Alliance to Save Our Antibiotics brings together health, medical, civil-society, farming, and animal-welfare groups and campaigns to stop the overuse of antibiotics in animal farming. It was founded in 2009 by Compassion in World Farming, the Soil Association and Sustain. https://www.saveourantibiotics.org/ (accessed on 30 March 2021).	UK
National Plan against Antibiotic Resistance	3	Policy instrument	National	Public	Voluntary reduction	A strategic action plan with the objective to reduce the risk of antibiotics resistance and, consequently, to reduce the impact of such on the health of people and animals, while sustainably preserving the efficacy of existing antibiotics. https://www.who.int/es/news-room/fact-sheets/detail/resistencia-a-los-antibi%C3%B3ticos (accessed on 30 March 2021). https://resistenciaantibioticos.es/es https://www.mscbs.gob.es/biblioPublic/publicaciones/docs/bacterias.pdf (accessed on 30 March 2021).	ES
Action plan to reduce antimicrobial resistance in the field of veterinary medicine for the period 2019–2023	2	Policy instrument	National	Public	Voluntary reduction	The action plan is mainly focusing on awareness raising and monitoring, with an objective to significantly reduce the usage of certain antibiotics. https://www.agri.ee/sites/default/files/content/arengukavad/tegevuskava-amr-2019-2023.pdf (accessed on30 March 2021).	EE
Soil Association private initiative	2	Voluntary initiative	National	Private	Voluntary reduction	Collection of detailed information on current usage of antibiotics in the UK amongst our licensees, to drive further reductions through sharing best practice.	UK
				External input			
Initiative	**Satisfaction level [1–5]**	**Tool**	**Geografical coverage**	**Nature**	**Mechanism**	**Description**	**Responder country**
Naturland standards	5	Voluntary initiative	International	Private	Prohibition of use	Manures from factory farming are not permitted. Limitation of sources (no conventional slurry or chicken pellets) and limitation of amount to 40 kg N in arable farming. www.naturland.de (accessed on 28 March 2021).	DE
RELACS—issues of contamination in recycled bioresources for agriculture	4	Project	International	Private	Promotion of alternative inputs	Series of webinars looking at possible contaminants in bio-resources such as sewage and household waste.	UK

Table A1. *Cont.*

Soil Association Standards	3	Voluntary initiative	International	Public	Prohibition of use/need of declaration/ justification of use	Covers standards and the conditions for fertilizer and soil conditioners use in Soil Association crop production. https://www.soilassociation.org/media/15931/farming-and-growing-standards.pdf (accessed on 28 March 2021).	UK

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