LEX4BIO

Report on drivers and barriers regarding the replacement of conventional fertilisers by bio-based fertilisers (BBFs) for all stakeholders in the value chain

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Mineral and Energy Economy Research Institute
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OPTIMISING BIO-BASED FERTILISERS IN AGRICULTURE – PROVIDING A KNOWLEDGE BASIS FOR NEW POLICIES

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LEX4BIO aims to reduce the dependence upon mineral/fossil fertilisers, benefiting the environment and the EU's economy. The project will focus on collecting and processing regional nutrient stock, flow, surplus and deficiency data, and reviewing and assessing the required technological solutions. Furthermore, socioeconomic benefits and limitations to increase substitution of mineral fertiliser for bio-based fertilisers (BBFs) will be analysed. A key result of LEX4BIO will be a universal, science-based toolkit for optimising the use of BBFs in agriculture and to assess their environmental impact in terms of non-renewable energy use, greenhouse gas emissions and other LCA impact categories. LEX4BIO provides for the first-time connection between production technologies of BBFs and regional requirements for the safe use of BBFs.

The project runs from June 2019 to May 2024. It involves 20 partners and is coordinated by LUKE (LUONNONVARAKESKUS - Natural Resources Institute Finland).

More information on the project can be found at: http://www.lex4bio.eu

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Introduction

The excessive use of natural resources in agriculture is a major concern for the future of our planet. Specifically, the extraction of fossil fuels and phosphate rock is causing increasing alarm among experts in the field (El Bamiki et al., 2021; Vaneeckhaute et al., 2013). Fossil fuels are integral to the production of nitrogen-based fertilisers, which are used extensively in modern farming practices. The widely-used Haber-Bosch process, a highly energy-intensive method, is used to fix atmospheric nitrogen and transform it into ammonia (Glibert et al., 2014; Schütz, 2017). Unfortunately, the availability of phosphorus deposits is severely limited to only a few countries, such as Morocco, Russia, Kazakhstan, Syria, Algeria, China, and Vietnam (Smol, 2019). Additionally, there is no consensus among researchers regarding the estimated time of depletion of the raw phosphorus reserves. Several studies suggest that phosphate rock reserves could be depleted within 50–100 years (Cooper et al., 2011; Cordell and White, 2013; Steen, 1998; Vaccari, 2009), whilst others suggest that phosphate rock reserves will be depleted shortly (Cordell et al., 2009). Regardless of these timelines, it is evident that this depletion will result in a shortage of essential nutrients for crops, and will have a significant impact on the ability to produce food. Therefore, it is clear that the future of our planet is at stake without access to these vital resources.

In response, farmers, scientists and industry experts have been searching for a reliable and efficient secondary fertilisers that can supplement or replace traditional fertilisers. One of the potential sources are waste-based materials, which have a long history of use in agriculture. However, the use of waste as fertilisers is not universally accepted and attitudes towards this practice vary across different regions of the globe. Given the long-standing practice of utilising waste-based materials in agriculture, Figure 1 depicts the sources of phosphorus and highlights the divergent approaches of societies across different regions of the world towards recycling waste as fertilisers, particularly for food cultivation (Cordell et al., 2009; Ipsilantis et al., 2018). As the need for food production is on the rise, it is imperative to seek out remedies that can satisfy the nutritional needs of crops while diminishing our dependence on finite resources.

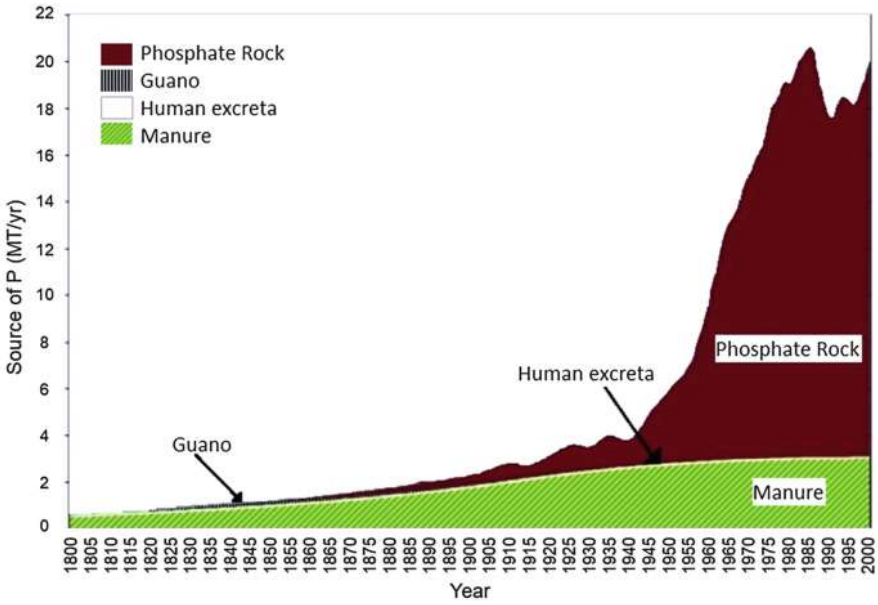


Figure 1. Historical global sources of phosphorus fertilisers (Ipsilantis et al., 2018).

According to the information presented in Figure 1, it is evident that the utilisation of bio-based fertilisers (BBFs), also referred to as organic or bio-fertilisers, has a historical background dating back to the 19th century. During this time, the practice of employing animal manure was widespread as a means to enhance the productivity of crops. Human excreta and guano were also used as fertilisers. However, the global demand for food production after 1945 led to the reliance on mineral-based fertilisers, such as phosphate rock, which could cause negative environmental impacts, including surface water eutrophication. This phenomenon led to the emergence of harmful algal blooms and oxygen-depleted dead zones in water ecosystems since the 1960s and 1970s (Diaz and Rosenberg, 2008). To prevent the depletion of essential nutrients for food production and mitigate the environmental impact of eutrophication, it is essential to shift towards highly bioavailable bio-based fertilisers as a replacement for synthetic or chemical fertilisers. Therefore it is important to take specific actions aimed to identify, evaluate and implement a sustainable strategies that can provide a safety on the European fertilisers market, and thus also provide access to raw materials for plant production in the European Union (EU) and all other countries. Such approach is included in the newest strategy of the EU's growth – the European Green Deal (EGD), that included a strategic block - a circular economy (CE), which is an economic model

focused on resources efficiency. It includes perspective of both - raw materials (resources) management and waste management. In the case of fertiliser sector, the transformation to the CE model has great potential for success of implementation. First, more sustainable use of fertilisers from primary sources and fertilisation methods should be promoted and implemented, which concern the main users of fertilisers that are, farmers, but also nurserymen. Secondly, many waste streams (including food waste, sewage sludge, manure, and others) can be successfully used as substitutes for commercial fertilisers. These two approaches may significantly accelerate the transformation towards the CE, as so far the European Commission (EC) introduced many recommendations and strategic documents in this regard (Smol 2021).

When introducing a new product to the market, it is essential to consider economic conditions, opportunities, and barriers that could impede the achievement of intended objectives. Utilising waste to produce fertilisers can potentially address issues of nutrient losses and deficiencies, as well as contribute to the reduction of biodegradable waste in landfills and encourage technological advancements. However, the production and use of these fertilisers may pose technological and financial obstacles, as well as face objections from various stakeholder groups. Overcoming such barriers may require long-term goals and collaboration among numerous sectors and entities, including legislative changes. The social reception of new products can be influenced by the development of nutrient recovery methods, which can adjust product features to meet the requirements of potential buyers. Thus, obtaining a thorough assessment of the feasible opportunities and prerequisites for BBFs to become standard, valued, and broadly accepted commercial products is crucial.

The current report presents an inventory of drivers and barriers regarding the replacement of conventional fertilisers by BBFs for all stakeholders in the value chain (Consumers, Farmers, and Fertiliser Producers, including Food and Beverage Producers).

Materials and Methods

The research in this report was conducted using a variety of research methods. In order to organise the information, the research scheme presented in Figure 2 was used.

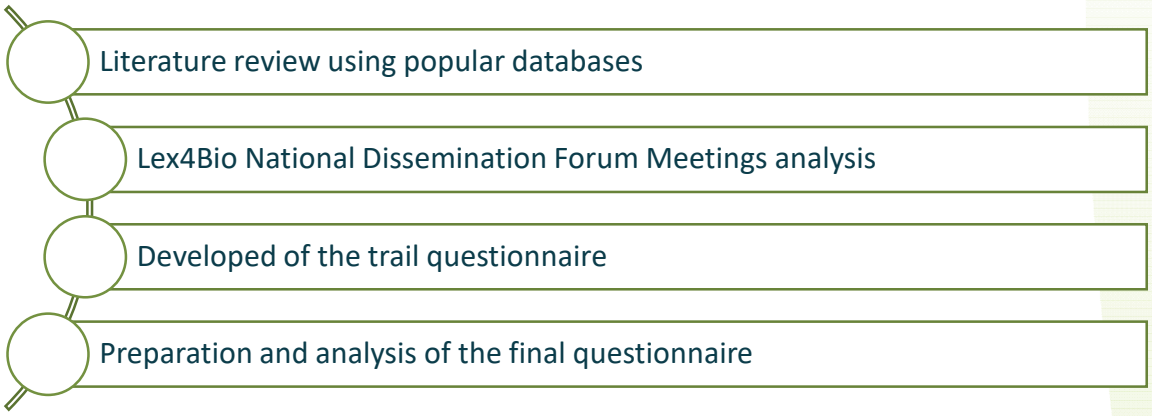


Figure 2. Research scheme.

The development of the above research scheme made it possible to prepare this report in accordance with the assumptions.

Literature review

The review of available data on drivers and barriers regarding the replacement of conventional fertilisers by BBFs for all stakeholders in the value chain was based on the analysis of current, available publications using the desk research method. Data sources analysed included peer-reviewed scientific publications that were published in popular databases such as Elsevier Science Direct, Elsevier Scopus, Multidisciplinary Digital Publishing Institute (MDPI) and Google Scholar (Smol et al., 2020). Keywords were used such as “bio-based fertilisers”, “drivers for bio-based fertilisers use”, “barriers for bio-based fertilisers use”, “awareness for bio-based fertiliser use”, “benefits for bio-based fertilisers use”, “bio-based fertilisers use by farmers”, “stakeholder’s types for bio-based fertilisers use”. The purpose of this step was to identify the relevant stakeholder groups for the use of BBFs in agriculture and the initial phase of assessing the level of acceptance for the implementation of BBFs in agriculture for the identified stakeholder groups.

Lex4Bio National Dissemination Forum Meetings

Examining the reports from Lex4Bio National Dissemination Forum (NDF) Meetings enabled extracting valuable insights from experts, scientists, and individuals associated with agriculture. These gatherings brought together stakeholders to share knowledge and engage in discussions. The reports were scrutinised to identify the factors that drive or hinder the production and usage of bio-based fertilisers, drawing from the expert presentations and the questions and comments that arose during the meetings.

Although the project representative took part in the meeting held in Belgium, it is important to note that it was not an official meeting of the Lex4Bio project. Meeting dates and organising countries are presented in Table 1.

Table 1. National Dissemination Forum Meetings.

Meeting date	Organizer
11-14.06.2019	Poland
19.06.2019	Belgium
01.10.2019	Denmark
15.11.2019	Germany
20.11.2019	Austria
13.11.2019	Switzerland
04.12.2019	Finland
14.12.2019	Poland
26.03.2020	Netherlands
05.10.2020	Spain
22.06.2022	Austria
07.07.2022	Denmark
17.08.2022	Finland
16.11.2022	Switzerland

Trial survey

The trail questionnaire was developed by conducting a comprehensive review of literature that focused on research conducted on farmers from various countries, as well as analysing reports from Lex4Bio National Dissemination Forum Meetings. The questions included in the questionnaire were formulated after considering the strengths, weaknesses, opportunities, and threats identified through analysis of the published research, legal regulations, and the unique features of the agricultural sector in Europe. The questionnaire aimed to explore the farmers' knowledge about waste-based, mineral, and organic fertilisers, as well as their current or future use. Understanding the key features of fertilisers can help tailor the products to meet the consumers' needs, enhancing trust and increasing the likelihood of acceptance of bio-based fertilisers.

The trail questionnaire was developed and distributed among Polish farmers. All Polish Agricultural Advisory Centres (16 institutions) were provided with the trial questionnaire with 54 questions for the survey, with whom the collaboration was established. Each relevant Agricultural Advisory Centre in the 16 voivodeships of Poland was entrusted with conducting a survey on a sample of 50 farmers, resulting in the anticipated return of 800 completed questionnaires from all parts of Poland. Due to the unique nature of Polish farmers as a social group, who frequently face limited access to technology, interviews were chosen as the method for conducting the survey. These interviews were conducted using paper questionnaires and pens, employing the PAPI (Paper and Pen Personal Interview) method. An electronic version of the questionnaire was provided to each of the Agricultural Advisory Centres, along with instructions for agricultural advisors who were responsible for conducting the survey. These instructions included clarifications and definitions of specific terms or concepts used in the questionnaire. The aim was to ensure that advisors were well-prepared to address any questions or concerns raised by farmers during the survey. The survey deadline was December 31, 2021.

Moreover, to expand the research group, the survey questionnaire was also made available on the internet.

Final survey

The trail questionnaire was a base for development of final questionnaire, that was distributed among several EU countries. The final questionnaire consisted of questions that were formulated by analysing the findings of the preliminary survey that was carried out in the 16 voivodeships of Poland, as well as scrutinising the reports from Lex4Bio National Dissemination Forum Meetings. The stakeholders were classified into three groups: Consumers, Farmers, and Fertiliser Producers (including Food and Beverage Producers). Each of these groups was provided with a specialised questionnaire, with questions that were exclusively designed to cater to their respective needs.

The consumer survey was carried out in Belgium, Denmark, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Spain, and Sweden. Similarly, the farmer survey was conducted in Austria, Croatia, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Poland, Romania, Spain, and Sweden. Finally, the fertiliser producers' survey (including food and beverage producers) was conducted in Austria, Denmark, Finland, Germany, Ireland, Poland, Portugal, Slovakia, Spain, and Sweden. The surveys were available and promoted on the internet. The survey deadline was April 30, 2023.

Reports from Lex4Bio National Dissemination Forum Meetings

The stakeholders found the project interesting, but they expressed concerns due to the necessary legal, technological, and social changes. Moreover, a lack of knowledge about processing, the impact of BBFs, and stakeholders' attitudes toward recycled material products are potential issues that need to be addressed. Presented issues and comments emphasised the importance of obtaining approval at each stage of the cycle, including selective waste collection, recycled material processing, and trade, used by farmers, food production, and ultimately consumers. Arguments and comments presented during Lex4Bio National Dissemination Forum Meetings concerning waste-based fertilised issues were relevant to all stakeholder groups. Examining the concerns and remarks raised in meetings enabled the recognition of barriers and drivers for the stakeholders involved in the value chain. The potential barriers resulting from the use of bio-based fertilisers are listed in Table 2.

Table 2. Barriers for the use of bio-based fertilisers identified by National Dissemination Forum Meetings.

Barriers	
Aspect	Description
Content and form variety	Due to the diverse sources of recycled materials, the varying forms, and nutrient contents, it becomes essential to process waste materials to acquire uniform fertilisers that satisfy both regulatory requirements and crop demands. The composition of certain materials, such as manure or municipal waste, may fluctuate from year to year, leading to variations in nutrient ratios and contamination levels. Consequently, it becomes impractical to establish universal recommendations applicable to all plant types and member countries.
Processing costs	Not every waste treatment facility possesses the financial capability to invest in a nutrient recovery system, such as a

	manure fraction separator. In order to achieve the desired characteristics and necessary quality of the final products, which includes the removal of heavy metal contamination, the implementation of costly and complex technical solutions becomes necessary. These solutions may prove to be unprofitable if there is an insufficient quantity of secondary raw materials available. Some types of contaminants cannot be effectively eliminated through thermal or chemical processes, rendering certain materials unsuitable as substrates for the production of bio-based fertilisers. The limited availability of raw materials, due to quality requirements, can result in higher processing costs and an increased price for the final product.
Transport costs	In order to centralise the production network and encourage the recycling of nutrients on a larger scale, it is recommended to shift production from local facilities to larger plants. However, this transition may not be financially viable, particularly when considering the associated transportation costs. The costs of transportation are dependent on factors such as the nutrient content or volume of the waste, both of which can vary.
Nutrient imbalances	In international trade, it is crucial to assess nutrient balances to prevent the necessity of increasing the usage of mineral fertilisers. The combination of surpassing permissible nutrient concentration limits and importing livestock feed, such as soybean, can result in nutrient losses and environmental pollution in countries with dense livestock populations.
Legal limitations	The lack of alignment between national regulations and those of the European Union (EU) can hinder waste trade among member states. Another issue raised pertains to the insufficient phosphorus content relative to the nitrogen content in waste

	materials. Meeting the nitrogen requirements of crops may result in surpassing permissible concentrations of phosphorus and contaminants like cadmium. Additionally, there is a challenge related to the incompatibility between fertiliser regulations and organic farming guidelines.
Value and price	Bio-based fertilisers may exhibit reduced effectiveness compared to mineral fertilisers, and their plant availability has not undergone comprehensive testing. Additionally, they tend to be more costly than organic fertilisers, which farmers often acquire without charge. Introducing financial incentives, such as taxes on landfilling or mandatory nutrient recovery, may be necessary. Importantly, the burden of these incentives should be shouldered by society rather than farmers.
Distrust	Although farmers who utilise bio-based fertilisers express satisfaction with the outcomes, they hesitate to openly communicate their product preferences. Their concerns stem from apprehensions regarding consumers' attitudes towards the yields achieved through the application of bio-based fertilisers.
Profitability	The environmental advantages stemming from the utilisation of waste fertilisers are not easily quantifiable in monetary terms. Therefore, if, despite the confidence gained by farmers, it is discovered that bio-based products lead to reduced yields, compensation may need to be considered. In such cases, bio-based fertilisers may not be regarded as a complete and satisfactory product.
Environment (and livestock care)	The lack of clear guidelines for using waste fertilisers poses risks of overdosing, soil and water contamination, CO_2 emissions, challenges in dosage determination, potential harm to animals through dust emissions and consumption of granular fertilisers,

	and objections from vegans and vegetarians due to concerns for animal welfare.

Although some concerns were raised during the meetings, the stakeholders recognised the potential benefits and opportunities that could arise from the implementation of the project's objectives and the increased use of fertilisers from waste. Therefore, despite the challenges and concerns, stakeholders acknowledged the potential for positive outcomes resulting from the project's objectives. The most important drivers for the use of bio-based fertilisers are presented in Table 3.

Table 3. Drivers for the use of bio-based fertilisers identified by National Dissemination Forum Meetings.

Drivers	
Aspect	Description
Frugality of natural resources and supply independence growth	Utilising waste as a substrate for fertiliser production offers multiple benefits, including a reduction in the utilisation of primary sources, minimising nutrient losses, mitigating environmental pollution, and decreasing economic reliance on external nations. This approach promotes the recovery of waste materials instead of resorting to landfilling practices.
Technological development	The production of bio-based fertilisers can be integrated with energy generation, specifically through biogas production. Advancements in recovery technologies have the potential to lower costs and enhance the quality of the end product. Technological progress can also create new possibilities for managing contaminants in waste or detecting substances that pose challenges in their removal.
Beneficial effect on soil (and atmosphere)	Bio-based fertilisers, owing to their carbon content, enhance soil fertility and mitigate the risk of soil erosion, while also exerting a positive impact on soil microorganisms. The inclusion of sulphur

	and micronutrients in these substances enhances their value as fertilising products. Furthermore, their involvement in carbon sequestration contributes to a decrease in atmospheric CO_2 levels, thereby reducing the greenhouse effect.
Ecological awareness increase	Establishing trust among farmers regarding new products can be achieved through research, knowledge dissemination, and the establishment of robust quality control systems. Some opinions indicate that bio-based fertilisers have gained acceptance, including within the organic farming sector. The younger generation of farmers, who are increasingly aware of the importance of organic carbon in fertilisers, could be a receptive target group for these products.
Opportunities due the materials and methods diversity	The production of bio-based fertilisers can utilise various types of waste without differentiation in the Fertiliser Regulation, as it treats all bio-based fertilisers equally, regardless of the substrate used. Additionally, EU law does not extend to products defined by national law, granting Member States the authority to determine the standards they wish to enforce.

Literature review

Assessing the significance of specific stakeholders can be challenging, but considering that the economy operates based on market supply and demand, it appears that farmers, being the primary end-users, are the crucial stakeholders whose views on bio-based fertilisers need to be examined (Jensen et al., 2016). Companies representing the food and beverage industry, as well as fertiliser producers, have a significant influence on the types of fertilising products utilised by farmers and the quality of consumed food. However, the quantity, quality, and type of food and fertilisers primarily result from the demand created by consumers and implemented in the fertiliser products market by farmers. Consequently, this report aims to analyse awareness, attitudes, and behaviours of three groups of stakeholders concerning the reuse of waste through the application of bio-based fertilisers in agriculture. The stakeholder's types that have been identified are presented in Figure 3.

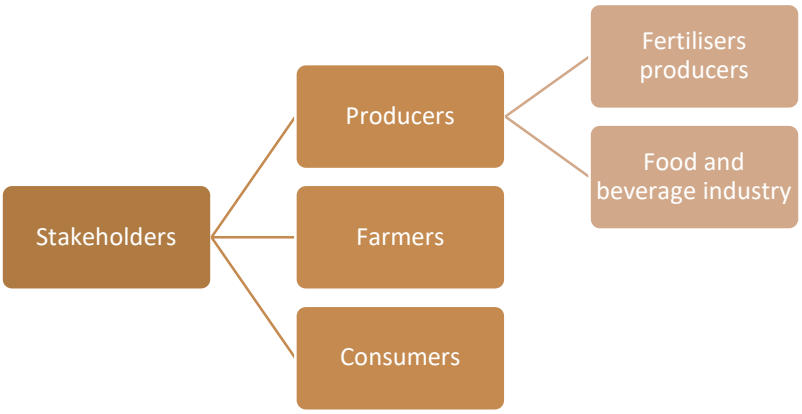


Figure 3. Stakeholders' types.

Waste based fertilisers can be produced from different types of waste (animal, plant, municipal), processed by different methods. The obtained fertilisers constitute a group of products, with various characteristics, often different than in the case of synthetic fertilisers (Jensen et al., 2016). For this reason, the stakeholder's attitude toward particular types of waste fertilisers may differ.

Farmers

As already mentioned, the literature review concerned the use of various waste streams as bio-based fertilisers. This chapter presents research on farmers' attitudes to fertilisers, broken down by specific waste streams:

- human waste,
- sewage sludge,
- animal waste,
- green and food waste,
- group of unidentified bio waste.

Case 1 – human excreta

In the first case, the research on the factors that affect the acceptance by farmers of fertilisers derived from human waste in South Africa was conducted by (Gwara et al., 2022). All methods used in this study were performed in accordance with the guidelines and regulations of the Ethics Committee for Research in the Humanities and Social Sciences. The general characteristics of the surveyed respondents conducted by (Gwara et al., 2022) was present in Table 4.

Table 4. General characteristics of the surveyed respondents (Gwara et al., 2022)

General number of respondents	341
Number of women [%]	68.2%
Number of men [%]	31.8%
Average age of surveyed respondents [years]	54
Average age of surveyed respondents [years]	23.2
Farm size (respondents with farms smaller than 1 hectare) [%]	77.4

The overall results of the study showed that farmers' attitude towards the use of human waste in agriculture was positive, meaning that farmers were willing to use bio-based fertilisers based on this waste stream. However, farmers recognised some health risks associated with the use of human waste in agriculture. Their negative attitude towards health safety issues

related to perceived behavioural control, including skills or self-efficacy, pathogens and pharmaceutical hazards. About 77% of farmers agreed to recycle human waste as co-compost. Farmers were also very positive about buying compost made from human waste and expect other people to buy food produced using co-compost as fertiliser. Approximately 103 farmers (31%) of the sampled farmers considered that the type of crops fertilised with human waste influenced their perception of the use of human waste. Of the 103 farmers, about 85% were willing to consume products fertilised with human waste if the fertilised crop was a product such as corn. A moderate 52% would eat vegetables, while only 41% would like to eat root or tuber crops fertilised with human waste. It follows that the influence of the type of cultivation, processing and cooking affected farmers' perceptions of the use of human waste. The study found that environmental awareness was positively related to willingness to recycle human waste. The perceived benefits may positively influence attitudes towards co-compost based on human excreta reuse (Gwara et al., 2022).

Case 2 – human urine

The next case (Simha et al., 2017) analysed an interview with 120 randomly selected farmers from Vellore in South India on the agricultural use of human urine. However, only 62 of the 120 farmers completed the entire survey. Therefore, 98 of the 120 farmers selected for the survey provided full socio–demographic data. The attitude of farmers to urine recycling, divided by socio-demographic variables is presented in Table 5.

Table 5. The attitude of farmers to urine recycling, divided by socio-demographic variables (Simha et al., 2017)

Variable		
Gender	N	Attitude
Male	80	Negative
Female	18	Positive
Age (years)		
<30	7	Negative
30-45	27	Positive/negative

45-60	40	Positive
>60	24	Negative
Family size		
≤3	14	Negative
3-4	32	Negative
4-6	39	Positive
>6	13	Positive
Farm size (ha)		
≤1	47	Positive
1-2	22	Negative
2-4	16	Negative
>4	12	Positive
Farming history (years)		
≤2	6	Negative
2-4	13	Negative
4-6	3	Positive
>6	76	Positive
Farm type		
Organic	13	Negative
Inorganic	26	Positive
Organic and pesticides	59	Negative

Moreover, the study included the analysis of the farmers opinion on human urine recycling by sorting them into 3 categories: farmers using fertilisation based on: inorganic fertilisers, organic fertilisers, organic fertilisers and pesticide. The results of the questionnaire regarding their opinion on using human urine is shown in Table 6.

Table 6. Opinion of respondents on using human urine in agriculture (Simha et al., 2017)

	Yes, good idea	Yes, very good idea	No, bad idea	No opinion
Inorganic farmers	45%	14%	27%	14%
Organic farmers	-	-	33%	33%
Organic and pesticide farmers	35%	13%	25%	27%

The farmers' opinions differed depending on the type of farm. There were no organic farmers which thought that using human urine as a fertiliser was a good idea and that people on the market would buy food fertilised with human urine, and 48% of inorganic farmers think so. Some farmers believe that the lower price of products fertilised with human urine may encourage consumers to buy. 62 respondents answered the question about incentives/disincentives to a positive attitude towards human urine recycling. Respondents were divided into those who thought that recycling human urine was a good idea and those who thought it was a bad idea, then they were asked to take a few statements, which are presented in Table 7.

The main factors that motivated the farmers to respond positively to the possibility of using human urine were soil quality and potential gains from reduced chemical fertiliser use. Farmers who thought that using human urine as fertiliser was a bad idea were motivated mainly by the fact that they use animal manure and do not need to use human urine and that people will mock or make fun that they use human urine as fertiliser. Furthermore, regardless the farmers' responses or their position on various issues, there was an interest in recycling and reusing human waste in agriculture (Simha et al., 2017).

Table 7. Factors that encourage/discourage positive and negative attitudes to urine recycling (Simha et al., 2017)

		Yes	No	Cannot say
Using human urine is a good idea	Good for soil quality	83%	3%	14%
	Increases crop productivity	54%	8%	39%
	Human urine is good if sanitised and used safely	78%	3%	19%
	Lesser need for chemical fertiliser	75%	8%	17%
Using human urine is bad idea	Crops can die	65%	33%	4%
	Taste of crops and vegetables will change	46%	42%	12%
	I use animal manure, so I don't need human urine	92%	4%	4%
	Health risks associated with human urine	46%	46%	8%
	The smell of human urine is hindrance	61%	30%	9%
	People will mock me or make fun of me	85%	11%	4%
	I will never use human urine	70%	26%	4%

Case 3 – sewage sludge

Rashid et al. (2017) analysed the social attitude to the possibility of using this method of sludge use. The study was carried out with 106 randomly selected farmers from West Bank, Palestine (41 farmers from Anza and 65 farmers from Beit Dajan). It was planned then to build two sewage treatment plants near the examined area, which was to contribute to the production of a significant amount of sewage sludge. Inhabitants of these two villages rely heavily on agriculture for living. Currently, there are no laws, rules, or regulations that require, recommend, and/or prohibit application of sludge for agricultural purposes in the West Bank. Table 8 presents the farmers opinions on sewage sludge use as a fertiliser in the West Bank.

Table 8. Opinions on sewage sludge by farmers in the West Bank (Rashid et al. 2017).

	Yes	No
Accept the idea to build a wastewater treatment plant	96%	4%
Know the meaning of sewage sludge	83%	17%
Know that sludge has benefits to soil and for agriculture uses	84%	16%
Agree to use sludge for agriculture	82%	12%
Sludge is disgusting material	42%	58%

Research has shown that most farmers are aware of the benefits of using sewage sludge on land, have adequate knowledge on the subject and accept the use of sludge as fertiliser on the ground. The questionnaire helps to understand what are the drivers and concerns connected with considering of using sewage sludge as a fertiliser among West Bank farmers (Table 9 and 10).

The survey showed what main factors influence of higher acceptance level of using sewage sludge (Table 11). The treated sewage sludge is not available for the studied region because the West Bank does not yet have a wastewater treatment plant. Thus, farmers were asked if in the future treated sludge would be available, they would use it. Out of 106 farmers asked, 81 answered the question. The answers are presented in the Table 12. 76% of farmers replied that they accept the use of sludge in agriculture, while 24% reject this possibility. Farmers declared that they intend to use the sludge for fertilising fruit trees, growing vegetables and other greenhouse plants.

Table 9. Factors that affect farmers' willingness to use sludge for agriculture in the West Bank (Rashid et al. 2017).

Factor	Share of farmers willingness
Price of sludge	22%
Public acceptance to buy crops fertilised by sludge	38%
Public health risks	16%
Religious reasons	4%
All of these	20%

Table 10. Main disadvantages of sludge application identified by farmers (Rashid et al. 2017).

Disadvantage	Share of respondents
Public health	15%
Environment	14%
Agriculture	2%
Soil	3%
Ground water	3%
Economy	2%
All of these	61%

Table 11. Main goals in sewage sludge application by farmers on lands in the West Bank (Rashid et al. 2017).

Goal	Share of respondents
Avoid health risks	7%
Protect environment	13%
Protect economic interests	35%
All of these	45%

Table 12. Factors of sludge use in agriculture (Rashid et al. 2017).

	Farmers who rejected using sludge	Total farmers
Psychological	20%	5%
Social	4%	1%
Public health	32%	8%
Religious	4%	1%

Perception of sludge as being unclean	12%	3%
Cheating oneself and others	8%	2%
All of these	20%	5%
Total farmers who rejected using sludge	100%	24%
Total farmers who accepted using sludge	-	76%
Total farmers	-	100%

Table 13. Reasons for not consuming crops that are fertilised with sewage sludge (Rashid et al. 2017).

	Farmers rejected consuming crops fertilised with sewage sludge	Total farmers
Psychological	33%	8%
Social	8%	2%
Public health	29%	7%
Religious reasons	8%	2%
All of above	21%	5%
Total	-	23%
Total farmers who accepted consuming crops fertilised with sewage sludge	-	77%
Total farmers	-	100%

The collected questionnaires have shown that farmers' opinions on the use of sludge on land may depend on the price of the sludge. If the sludge is not expensive, it is safe and does not pose a threat to health, it has a greater chance of good reputation among farmers. According to the finding of Rashid et al. (2017) there is a need to educate farmers about the benefits of using sewage sludge to land, but the general opinion of most farmers about the use of sewage sludge on soil is positive.

Case 4 – wastewater

Municipal wastewater is a valuable source of biogenic substances (Sheidaeia et al., 2016). However, due to the treat of polluting the soils with heavy metals or hazardous microorganisms the direct application of wastewater in agriculture is less and less often considered in developed countries. Due to limited irrigation water sources in some regions located in dry climate this method for combined fertilisation and irrigation is still used. The farmers' attitude towards wastewater use in Fars Province, Iran was investigated by Sheidaeia et al., (2016). Among health-related risk the survey respondents indicate the following factors presented in Table 14.

Table 14. Farmers' perceived health risks of wastewater (Sheidaeia et al., 2016).

	Health risks			
	Very low	Low	High	Very high
Viral, bacterial and protozoan infection among consumers	48.1%	41.7%	8.3%	1.9%
Prevalence of infectious diseases	25%	59.3%	13.9%	1.9%
Toxicity of crops and vegetables	2.8%	13%	78.7%	5.6%
Health risks for farmers and their families	50%	38.9%	8.3%	2.8%

Most farmers (84.3%) found the toxicity of crops and vegetables irrigated with sewage. This may be due to the presence of heavy metals and pesticides, while only 11.1% of farmers said health risks for them and their families. Therefore, the study covered the aspects of farmers perception of using wastewater for soil irrigation. The results are shown in Table 15.

Table 15. Perceived impacts of wastewater irrigation on environment (Sheidaeia et al., 2016).

	Environmental risks			
	Very low	Low	High	Very high
Reduced soil quality	12%	34.3%	42.6%	11.1%
Increased environmental degradation	31.5%	43.5%	19.4%	5.6%
Degraded groundwater quality	48.1%	38%	13.9%	-

According to Table 15, the farmers had different approaches to the quality of soils irrigated with sewage. 53.7% of farmers recognised high or very high degradation of soil quality, while 46.3% of farmers did not notice any problem with the quality of soils previously irrigated with sewage. Differences in perceived soil quality were the result of the duration of wastewater application. Long-term use of wastewater can increase the amount of salts and heavy metals into the soil and reduce productivity (Sheidaeia et al., 2016).

Case 5 - attitudes to bio-based fertilisers as a replacement for conventional fertilisers

Barragán-Ocaña et al. (2016) in their study analysed among other the farmers attitude to using bio-based fertilisers. The study sample belongs to a group of farmers from the State of Morelos, Mexico, with individuals from nine regions of the state: 1. Cuautla, 2. Quilamula, Tlaquiltenango, 3. Achichipico, Yecapixtla, 4. Ocuituco, 5. Zacatepec, 6. Tlayacapan, 7. La Tigra, Puente de Ixtla, 8. Ayala, and 9. Atotonilco, Tepalcingo. I total, more than 70 peasant producers were interviewed and surveyed. Categorical statements in an affirmative form were included in each category to measure the degree of agreement or disagreement using a Likert scale with the following options: 1. Strongly disagree, 2. Disagree, 3. Undecided, 4. Agree, and 5. Strongly agree. The higher the score was, the greater the degree of agreement with the expressed statements. The results are shown Table 16.

Table 16. Statements concerning the effect of using bio-based fertilisers for each category (Barragán-Ocaña et al. 2016).

Category	Questions	Obtained average responds	Average by category	Overall average
I: Technical and economic development	1. Since using these bio-based fertilisers, the profits I receive from the produced crops have improved.	4.3	4.3	4.4
	2. The use of bio-based fertilisers has been of greater economic benefit for me than, for example, chemical fertilisers.	4.5		
	3. Bio-based fertilisers produce the same or better results year after year regardless of changes in climate.	3.9		
	4. Learning to use bio-based fertilisers has been simple and their cost highly affordable.	4.5		
	5. I consider that using bio-based fertilisers involves minimal risk to me, both technically and economically.	4.4		
	6. I am sure that bio-based fertilisers have more advantages than disadvantages.	4.6		
II: Productivity and environmental protection	7. Bio-based fertilisers are a technology that does not harm the environment and increases the quantity and quality of crops.	4.5	4.5	
	8. Using bio-based fertilisers, I have noticed that the quality and recovery of the land have improved significantly.	4.3		

	9. If I use bio-based fertilisers, I receive a higher yield per hectare than if I only use chemical fertilisers.	4.5	
	10. The use of bio-based fertilisers is less risky for me and for the soil than chemicals.	4.6	
	11. Using bio-based fertilisers enables the plant to grow faster and become more resistant to pests and weather changes.	4.5	
III: Social development	12. I believe that since using bio-based fertilisers, the profits I have received enable me to increase my welfare and that of my family.	4.3	4.4
	13. The use of bio-based fertilisers has improved my social status and obtained greater benefits for my family and/or me.	4.4	
	14. Thanks to the benefits of production and the ease of use of bio-based fertilisers, I have had more free time for my family and myself.	4.4	

The summary of the survey according to its authors was that 76% of respondents have greater acceptance than rejection of the favourable effect of using bio-based fertilisers. The study reveals the main barriers that can limit the benefits obtained from the use of bio-based fertilisers included the following:

1. The economic benefit obtained from a crop depends upon the crop type and the extent of the cultivated land.
2. If other major inputs (i.e., seed and irrigation) were absent, the expected benefits might be limited.

3. In many cases, it is necessary to conduct soil studies and, if required, apply the relevant treatment.
4. Training to apply fertilisers is important, and its lack affects yields.
5. Infrastructure is lacking.
6. The price of products on the market is low, and their positioning is difficult.
7. Government support for small-scale producers is lacking.

The authors suggest the following action which need to be taken to promote using bio-based fertilisers in the analysed region:

1. Promoting connections among all stakeholders.
2. The planning and administration of programs to stimulate innovation in line with reality and the needs of underdeveloped countries.
3. The generation of ad hoc programs that include small-scale producers to promote the modernisation of the countryside and address the needs of these producers.
4. The generation and facilitation of technology transfer mechanisms.
5. The construction of diffusion, awareness and training mechanisms.

Case 6 - attitudes to bio-based fertilisers as a replacement for conventional fertilisers

The farmers perception of bio-based fertilisers have been also investigated in Northeastern Thailand by Chouichom and Yamao (2011), who in 2008 have collected the opinion about the use of bio-based fertilisers from 100 farmers in the province of Surin, dealing with rice cultivation. Demographic characteristic of farmers is presented in Table 17. The attitudes of farmers towards bio-based fertiliser and their use are presented in Table 18.

Table 17. Demographic characteristic of farmers (Chouichom and Yamao 2011).

	Mean (100 farmers)
Age (years)	52.3
Education (years)	5.2
Family members (persons)	3.8
Farm area (m^2)	36 592
Experience with farm (years)	25.2

Table 18. Farmers' attitudes towards bio-based fertilisers and their use* (Chouichom and Yamao 2011).

	Mean	Level
Bio-based fertiliser can decrease weed quantity and chemical use	4.16	Agree
Bio-based fertiliser use can conserve soil humidity	4.03	Agree
Using bio-based fertiliser manure could decrease soil erosion and increase soil nitrogen fixation	4.11	Agree
Bio-based fertiliser use can cause soil turn loamy and thus make soil preparation and ploughing easy	4.49	Strongly agree
Bio-based fertiliser use can increase rice production and quality of rice	3.98	Agree
Bio-based fertiliser use can cause lower farm investment	4.01	Agree
Bio-based fertiliser use can help the environment better	4.14	Agree
Bio-based fertiliser use can increase organic matters in soil	4.11	Agree
New manure can be used for farm fertilisation immediately	3.22	Neutral
Ploughing rice stubble and weed stalk can increase organic matter in soil	4.09	Agree
Soil structure is mellow and pliable	4.08	Agree
Soil structure is tight and firm	2.51	Disagree

Soil structure is same as before	2.73	Somewhat
The percentage of broken rice seeds decreased	4.21	Agree
The percentage of broken rice seeds increased	2.63	Somewhat
The percentage of broken rice seeds has not changed	2.56	Somewhat
Pests and insects increased	2.58	Disagree
Rice plants are strong to resist diseases and insects	3.67	Agree

*The received responses were scored on a five-point Likert's scale ranging from "strongly agree (5)" to "strongly disagree (1)"

According to the study by Chouichom and Yamao (2011), the farmers have a positive attitude to the use of bio-based fertilisers. Farmers have noticed that soil in farms employing bio-based fertilisers could absorb more organic nutrients and conserve water humidity. This is especially so when they use bio-based fertiliser constituted by animal manure. Farmers agreed that using bio-based fertiliser manure could decrease soil erosion and increase soil organic matter. Farmers also concurred that bio-based fertiliser use could help soil become loamier and thus easier to plough. Farmers also believe that they can reduce fertiliser spending by producing their own bio-based fertiliser, such as manure. Farmers' opinions are positive when it comes to using such fertilisers immediately, because drying manure can cause loss of some nutrients. In addition, farmers said that they could increase quantity and quality of rice production by adding bio-based fertiliser. However, there were also some disadvantages and barriers indicated by the farmers which have been presented in Table 19.

Table 19. Disadvantages and barriers related to the use of bio-based fertilisers indicated by farmers (Chouichom and Yamao 2011).

Disadvantages and barriers	Respondents
Lack of knowledge and experience about bio-based fertiliser	63%
Little contact with soil extension worker	58%
The high cost of the transportation	55%
Growth of seed weed in manure	52%
Increasing frequency of insects and pests	49%

The study has shown that rice farmers have expressed a positive attitude towards bio-based fertilisers used on their rice farms, with most of them using bio-based fertilisers from their farm animals.

Case 7 - attitudes to bio-based fertilisers as a replacement for conventional fertilisers

The study on the use of bio-based fertilisers was carried by Pathak and Christopher (2019) on the socio-economic condition and constraints faced by the farmers in adoption of bio-based fertilisers in Bhadohi district in Uttar Pradesh, India. Their study was carried out in 2017-2018 in Abholi block of Bhadohi district. Six villages and 120 respondents were selected randomly for the survey and data were collected through personal interview method. It was found that majority of respondents (62.50%) had lack of awareness regarding knowledge of bio-based fertilisers, which was identified as a main barrier for their application in agriculture. Furthermore, lack of availability of bio-based fertilisers in general and bio-based fertilisers recommended for different crops were the next barriers identified with 58.3% and 55.8% respectively. Moreover, barriers such as lack of technical knowledge (54.2%), delay in processing and lacking credit facility (51.7%) and lack of knowledge regarding seed treatment (50.0%) were discovered among surveyed population. Table 20 show the constraints faced by the farmers in adoption the bio-based fertiliser.

Table 20. Constraints faced by the farmers in adoption the bio-based fertiliser (Pathak and Christopher 2019).

Barriers	Share of respondents
Lack of awareness among farmers regarding knowledge of bio-based fertilisers	62.5%
Lack of awareness among farmers regarding use of bio-based fertilisers	60.0%
Non-availability of bio-based fertilisers	58.3%
Lack of availability of bio-based fertilisers as per the recommendation of different crops	55.8%
Lack of technical knowledge regarding use of bio-based fertiliser	54.2%

Delay in processing and lacking in credit facility	51.7%
Lack of knowledge regarding seed treatment, use of sticking agents, its quantity and methods and use of sticking agents during seed treatment	50.0%

The issue of social acceptance of using bio-based fertilisers was also investigated in EU countries. In their study, Bencheva and Tepavicharova (2017) analysed the attitudes of farmers to bio-based fertilisers in Bulgaria. The study was conducted to obtain the opinion of 150 farmers regarding the use of bio-based fertilisers as an alternative to synthetic fertilisers. The analysed farms practiced conventional farming methods. Within the study a short questionnaire was distributed among the farmers to test their willingness of switch from mineral based fertilisers to bio-based fertilisers. The survey results are shown in Table 21.

Table 21. Knowledge and attitudes respondents about bio-based fertilisers (Bencheva and Tepavicharova 2017).s

	Respondents
Periodic import of chemical fertilisers	88.7%
Regular use of manure	40%
Willingness to replace chemical fertilisers with bio-based fertilisers	98.7%
Knows about bio-based fertilisers	80%
Belief that the use of chemical fertilisers and unprocessed manure provides the soil with the right amount of nutrients, and nitrate residues in the soil are within acceptable standards	60%

The study revealed that 88.7% of the respondents admitted that they periodically import chemical fertilisers during cultivation. According to farmers, the main advantage of chemical fertilisers is the protection associated with the appropriate content of nutrients. Another advantage pointed out by farmers is the ability of chemical fertilisers to secure crop production. Despite the advantages of this type of fertiliser, they are also aware of the disadvantages of such fertilisation. 40% of respondents say that they regularly use animal manure, mainly owners of farms. 98.7% of farmers expressed a desire to replace chemical

fertilisers with bio-based fertilisers, probably due to the fact that 80% of respondents declare that they have heard about bio-based fertilisers. One of the main reasons for the practice of conventional farming is the belief of farmers (60%) that the use of chemical fertilisers and unprocessed manure provides the soil with the correct amount of nutrients, and nitrate residues in the soil are within acceptable standards. The transition from chemical to bio-based fertilisers in Bulgaria is slow because most farmers find them more expensive and more difficult.

Case 8 – animal manure

Koelsch et al. conducted a survey of farmers (also agricultural advisors and animal feeding operations advisors) in Washington state. The survey focused on identifying the barriers and advantages of using manure as a fertiliser, with the aim of both, improving manure management and services adjustment to the stakeholders needs. 92% of the respondents assessed that manure positively influences and soil nutrient content and fertility. The majority also considered, that the effect of manure on soil properties is beneficial too. 79% appreciated manure effect on biological soil properties and 73% that indicates its effect on physical properties as beneficial. Slightly less, 69%, claimed, that manure definitely had a positive effect on yield changes. Interestingly, the respondents didn't assess the impact of manure application on the environment as clearly beneficial. As many as 32% stated, that the manure fertilisation practices bring harm to the environment. The authors suggested, that respondents have more knowledge about the damage caused by manure, than about the environmental benefits. The most frequently indicated barriers are presented in Table 22.

The authors noticed an imbalance between the perception of the advantages and disadvantages of manure - although many farmers saw the advantages of using natural fertilisers, the multitude of indicated barriers may explain the lack of use of animal manure as fertilisers in many farms. As the survey was the basis for assessing the educational needs of farmers and advisers, the authors concluded, that educational programs will significantly improve the perception of manure, increasing its value in the eyes of potential users.

Table 22. Barriers, identified by Washington State survey participants (Koelsch et al., 2020).

Barrier	Count
Transportation and application costs	90%
Odours	78%
Timeliness of application	72%
Field conditions limiting application	66%
Time/labour requirements	63%
Application equipment compaction	57%
Poor uniformity of application	51%
Regulations	50%
Weed seed from manure	48%
Initial costs for adding manure	46%

Case 9 - the factors, that farmers consider, when choosing fertilisers

(Case et al., 2017) conducted a survey, among Danish farmers, to identify the factors, that farmers take into account, when choosing fertilisers. The questionnaire consisted of 17 questions and included 3 groups of waste fertilisers (Table 23).

The study showed, that animal-waste based fertilisers (especially UNP) were much more popular, than fertilisers from urban waste. Nearly three third of respondents used one, or more type of organic fertiliser. Among the barriers identified by farmers in the use of fertilisers made of waste, the most important ones turned out to be:

- unpleasant smell,
- unreliable nutrient content,
- high equipment costs (applicators and processing equipment).

Table 23. Organic fertilisers groups (Case et al., 2017).

Group	Materials
UNP (Unprocessed animal waste)	Slurry, manure and urine
PRO (Processed animal waste)	Composted and thermally dried manure and slurry, digestate, acidified slurry, liquid and solid slurry separation products
URB (Urban waste)	Bio-compost from green and food waste, sewage sludge unprocessed or subjected to dewatering, thermal drying, anaerobic digestion or composting, mineral concentrates obtained from sewage sludge

The waste processing can be a solution to both, the odour problem (anaerobic digestion, composting, drying) and the uncertain nutrient content (anaerobic digestion, mechanical separation, acidification). As a solution to the problem of costly equipment, the authors suggest the introduction of a subsidy system for new equipment, that allows the application of alternative fertilisers and easier access to credits, for waste processing equipment. Supply-side problems are best illustrated by the fact, that over 40% of farmers interested in using alternative fertilisers, reported unavailability to their preferred type of fertiliser. Solving the problem requires many changes and improvements through different sectors e.g. improvements in regulations on trade (including international trade) and transport, new technologies (improvements in treatment plants, enabling the recovery of nutrients), subsidising and providing credit options to farmers who decide to buy machinery necessary for processing, improvements in online trade. At the same time, farmers appreciated the features of fertilisers from waste such as:

- soil structure improvement,
- low price,
- easy access.

The farmers showed great interest of future organic waste-based fertiliser use – close to 85% of respondents declared interest in implementing organic fertilisers on their farm, within 3 years from the survey. The greatest interest was aroused by PRO.

Tur-Cardona et al. (2018), carried out a discrete choice experiment to disclose, how farmers willingness to pay changes, depending on the selected fertiliser characteristics. The survey was conducted on 555 farmers, from 7 countries, divided into 4 groups presented in the Table 24.

Table 24. Groups of the surveyed countries (Tur-Cardona et al. 2018).

Group	Countries	Nutrient balance
The Benelux countries	Belgium, Netherlands	Surplus of organic nutrients
Denmark	Denmark	Neutral nutrient balance
Eastern European Countries	Hungary, Croatia	Negative net balance of organic nutrients
Central European Countries	France, Germany	Negative net balance of organic nutrients

In consultation with experts and stakeholders, 7 factors to characterize the fertilisers for the survey were selected. It was found, that the most important factors, from the point of view of the study, would be: price, form, volume, N-content uncertainty, organic carbon content, hygienisation and nutrient release rate. The results of the study indicated that farmers prefer cheaper fertilisers, than conventional ones, with a solid form and a certain nitrogen content. The authors noted, that there was generally a greater tendency to choose alternative fertilisers among younger farmers, who more frequently processed the manure. Interestingly, when faced with the choice between traditional and bio-based fertilisers, the majority of respondents from the 3 groups indicated the alternative fertiliser. The exception was Denmark - respondents from this group assessed traditional and alternative options at a similar level. The increase in willingness-to-pay (WTP)[1], was most influenced by factors such as form of

[1] WTP is defined as "the maximum price that a buyer accepts to pay for a given quantity of goods or services"

granules, hygienisation and the presence of organic matter. At the same time, WTP decreased, with nitrogen content uncertainty and volume increasing. Farmers WTP was 76% of the price of conventional fertiliser, which in the authors opinion means, that bio-based fertilisers production (and selling at a WTP price) may prove profitable in countries, where processing companies will be rewarded for accepting waste.

Consumers

Many bio-based products that are currently on the market are still considered by consumers as a new alternative because they are only recently available and therefore consumers are often unaware of the product's properties.

Case 1 – unidentified exact composition of bio-products

In this case, the research was conducted by (Laborda et al., 2023) in the form of online surveys in 4 European countries - Italy, France, Germany and Spain, on 1602 respondents. First, information on the characteristics of the respondents, such as gender, age, and financial situation, was collected. These characteristics are presented in Table 25.

Table 25. Characteristics of respondents (Laborda et al., 2023)

Gender	50.62% female 49.388% male
Age	31.17% aged 18-34 years 67.33% aged 35-64 years 1.50% aged >65 years
Economic situation	3.68% very difficult situation 13.84% difficult situation 53.55% situation sufficient to make ends meet 26.56% comfortable situation 2.37% very comfortable situation
Education level	9.91% primary education 18.83% secondary education 29.68% technical/occupational education 41.58% higher education
Location	50.84% cities 32.81% towns and suburbs 16.34% rural areas

Table 26. Level of agreement about statements related to bio-based products' purchase (Laborda et al., 2023)

	Answers Distribution [%]					
	Strongly + agree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
If I knew that bio-based products were available through a local store, I would be interested enough to look at it.	74	26	49	19	4	2
I would only consider buying bio-based products if the price is competitive with conventional ones.	72	25	47	20	6	2
I think that there is too much information to be analysed to know which is the best purchasing choice.	76	22	54	17	5	2
I make shopping with a lot of time to make a thoughtful choice of the products I am buying.	70	21	49	22	7	1
Price is a mean of simplifying	69	20	49	21	8	2

complicated purchasing choices.						
Products I am used to buy make shopping quicker and easier.	66	16	50	28	4	2
Labels are simple and understandable.	44	10	34	29	22	5
I know how to learn if a product is bio-based.	39	8	32	32	21	7
I believe my friends/family/colleagues would like me to buy bio-based products.	36	9	27	43	11	10

Respondents answered questions about the use of bioproducts on a scale of: strongly + agree, strongly agree, agree, neutral, disagree and strongly disagree. Questions and answers of respondents in % are presented in Table 26. The below-identified factors can be used as elements to facilitate public acceptance of bio-based and recycled products by analysing a survey on these products.

The survey results suggest that environmental benefits can be a useful factor in the buying process if understandable information is communicated clearly to consumers, as indicated by 74% of respondents. The most valued benefits seem to be related to health and safety, sustainable end-of-life of products, and natural origin and properties. Environmental awareness alone is not enough to ensure market openness - consumers will always look for quality and attractive prices (Laborda et al., 2023).

Case 2 - human excreta and urine

A different study on the acceptability of using human excreta for food production in South Africa was conducted by Duncker et al. (2007). The study was developsed in a rural settlements area in 4 different Provinces: Northern Cape, the Eastern Cape, KwaZulu-Natal and Limpopo. A total of 120 households were asked about their perception of human urine, human faeces and its influence on plants. The answers were including the respondent gender while in the rural area a completely different habits apply to both men and women regarding sanitation issues. Perception of human excreta, urine and using human excreta on plants were present in Tables 27, 28 and 29.

Table 27. Perception of human excreta (Duncker et al. 2007).

	Man	Women	In general
Potential fertiliser	25.2%	50.5%	38.2%
Waste	9.9%	15.3%	12.7%
Unhealthy	5.4%	6.3%	5.9%
Don't know	59.5%	26.1%	43.2%
Number of respondents	113	116	229

Table 28. Perception of human urine (Duncker et al. 2007).

	Man	Women	In general
Potential fertiliser	2.7%	1.8%	2.2%
Waste	23.0%	7.1%	14.8%
Harmful to plants	4.4%	1.8%	3.1%
Other	11.5%	56.6%	33.6%
Don't know	58.4%	35.4%	46.3%
Number of respondents	111	109	220

Table 29. Perception of using human excreta on plants (Duncker et al. 2007).

	Northern Cape	Eastern Cape	KwaZulu-Natal	Limpopo	In general
Potential fertiliser	0.0%	16.2%	3.4%	0.0%	5.3%
Kills plants	32.7%	0.0%	0.0%	0.0%	12.1%
Burns plants	49.0%	45.9%	58.6%	41.2%	49.2%
Harmful	14.3%	0.0%	0.0%	0.0%	5.3%
Unhealthy	0.0%	18.9%	0.0%	0.0%	5.3%
Smelly	4.1%	2.7%	0.0%	0.0%	2.3%
Don't know	0.0%	16.2%	37.9%	58.8%	20.5%
Number of respondents	49	37	29	17	132

Case 3 – human excreta and manure

Attitudes of rural societies in Mali and Nigeria to using human excreta in agriculture was analysed by Akeredolu et al. (2006). The results from both countries revealed knowledge state of both manure and human excreta use in farming. The analysis by Akeredolu et al. (2006) shows that the attitudes to human excreta use are mixed and predominantly influenced by traditional and religious beliefs. A total of 420 respondents were involved in the survey, with an average of 40 and 30 respondents per settlement in Nigeria and Mali respectively. The results of the survey are presented in Table 30.

Table 30. Replies regarding the question “is the use of human excreta in agriculture is acceptable to you?” (Akeredolu et al. 2006).

	Nigeria	Mali
Yes	42%	48%
No	51%	40%
Don't know	2%	12%
Decline to answer	5%	0%

It was assumed that 42% of respondents from Nigeria thought using human excreta in agriculture was acceptable and 51% thought it was not, 2% did not know and 5% declined to comment. Most of the respondents who thought human excreta reuse in agriculture was acceptable were from the indigenous population who were predominantly farmers. The respondents from the settlement of Mpape had the highest percentage of objections, to using human excreta in agriculture. It was observed that majority of the residents of Mpape were migrant settlers who were mostly construction site workers, which may explain their response and attitude to human excreta reuse in agriculture. In Mali, 48% of the respondents thought using human excreta in agriculture was acceptable while 40% thought it was not acceptable and 12% did not know. As Table X suggests, the respondents in Mali are more open to reusing human excreta in agriculture.

The second question from the survey was concerned about people attitude to eating food grown on human excreta. The results are shown in Table 31.

Table 31. Replies regarding the question "would you buy and eat food if you knew that it was grown using human excreta as a manure (Akeredolu et al. 2006).

	Nigeria	Mali
Yes	51%	46%
No	41%	54%
Don't know	3%	0%
Decline to answer	5%	0%

Regarding buying and eating food grown using human excreta as manure, in Nigeria, 51% of respondents would buy food grown using human excreta as fertiliser and 41% indicated they would not, 3% did not know and 5% declined to answer. In Mali, 46% of the respondents said they would buy food grown on human excreta and another 54% indicated that they would not. The Mali results show a slightly higher percentage of negative responses, which may be indicative of the influences of religious beliefs. The Islamic religion has well defined stances on purity (clean, unclean, pure and defiled) especially regarding bodily discharges and places significant restrictions on contact with excreta. It was that mostly farmers in both countries consider human excreta a source of cheap fertilising agents as they use septic tank effluent to irrigate their fields more for its nutrient value than for water.

Case 4 – human urine

Pahl-Wostl et al. (2003) investigated the consumer attitudes towards the new technology of urine separation and its possible application as a fertiliser in agriculture in Switzerland. Focus groups are deliberate, moderated group discussions with informed citizens on a certain topic. The majority of the citizens expressed their willingness to move into an apartment with a separating toilet and to buy food fertilised with urine. However, they were not willing to accept additional financial costs or efforts. The survey participants were asked if they could imagine eating vegetables fertilised with urine according to Table 32.

Table 32. Replies regarding the question “Can you imagine eating vegetables fertilised with urine?” (Pahl-Wostl et al. 2003).

	Man	Women
Yes	44%	11%
Rather yes	28%	63%
Rather no	8%	16%
No	16%	5%
No opinion	4%	5%

It can be assumed that a majority (72%) answered positively. Also 80% stated that they would prefer vegetable fertilised with urine to artificial fertiliser. Arguments in favour were related to the fact, that urine fertiliser is more natural. Moreover, the authors show that similar results from a survey in a Swedish municipality were obtained by Schmidtbauer (1996) reported. People pointed out the need to find an attractive name and develop good marketing to overcome the possible bias towards urine as a basis for fertiliser production. Despite this overall positive attitude participants emphasised that any health risks should be excluded. The respondents suggest that as long as potential sources for disease and threats to human health cannot be excluded, they would not welcome the application of human urine even when artificial fertiliser is not a very attractive alternative. Arguments related to long-term sustainability (closing nutrient cycles) were of less importance than arguments that relate directly to the effects of micropollutants on human and ecosystem health.

Case 5 – human excreta

The community perception of human excreta was analysed in Ghana by Mariwah and Drangert (2011). The study included a survey with 154 collected questionnaires from a peri-urban agricultural community regarding using sanitised human excreta as a fertiliser. The questionnaire consisted of an analysis of residents' attitudes towards human excreta in general (Table 33) and the social knowledge in terms of human excreta reuse as a fertiliser (Table 34).

As the analysis of community attitude to human excreta suggest that knowledge about the uses or benefits of sanitised human excreta can influence perceptions and attitudes as well as willingness to use it for agricultural purposes. Therefore, the authors formulated ten statements to find out residents' knowledge on the utilisation of human excreta as well as their willingness to use it as fertiliser.

Table 33. Residents attitude towards human excreta (Mariwah and Drangert 2011).

Statement	Agree [%]	Don't know [%]	Disagree [%]
Human excreta are a waste and suitable only for disposal	84.4	0.0	15.6
Handling excreta is a great health risk	96.8	0.6	2.5
Human excreta should not be handled in any way	72.1	3.2	24.6
Human urine has no benefit to humans	74.0	8.4	17.5
It is a taboo to handle urine	37.7	11.7	50.7
Human faeces have no benefit to humans	70.8	5.8	23.4
It is a taboo to touch faeces	43.5	12.3	44.1
It is a taboo to touch treated faeces	38.9	13.0	48.0

Table 34. Society knowledge in terms of human excreta reuse as a fertiliser (Mariwah and Drangert 2011).

Statement	Agree [%]	Don't know [%]	Disagree [%]
Human excreta are a resource for the soil	60.4	24.0	15.5
Sanitised human excreta cab be used as a fertiliser	57.1	29.2	13.6
I will use human excreta on my crops if sanitised	36.3	9.7	53.9
Taste of vegetables will change when fertilised with urine	25.3	28.6	46.1
Smell of vegetables will change when fertilised with urine	25.9	27.9	46.1
Crops can be killed when fertilised with urine	40.9	37.0	22.1
Crops fertilised with human excreta are good for consumption	42.2	14.9	42.9
I will never consume crops fertilised with human excreta	61.6	6.5	27.9
Animal manure can be used as a fertiliser	93.5	2.6	3.9
Ever used animal manure as a fertiliser	60.4	0.0	39.6

Moreover, the study investigated what types of factors that influence on the perception of reusing sanitised human excreta as a fertiliser on local crops. The findings are presented in Table 35. While technologies exist to recover human waste for agricultural use, scale-up of such innovations would mainly depend on public acceptance of the end products (Gwara et al., 2022).

Table 35. Factors that prevent residents from using sanitised excreta on their crops (Mariwah and Drangert 2011).

Factors	Sanitised faeces [%]	Sanitised urine [%]
Smell	17.5	51.9
Health risk	39.0	20.9
Appearance	18.2	6.5
Patronage will be poor	10.4	9.7
People will mock at me	0.6	0.6
Religious belief	0.6	0.6
None	13.6	9.7

Producers

No analysis of attitudes and opinions of fertiliser producers has been found in literature reports. The producers are a group, that has not been surveyed, on opinions about bio-based fertilisers use. On the one hand, food producers may be concerned about the brand's opinion, perceived as associated with the use of waste. Producers are likely to be guided by consumer preferences. On the other hand, perceiving food produced with the use of fertilisers from waste as environmentally friendly may positively influence the opinion of consumers, and thus encourage producers.

Barriers to the use of bio-based fertilisers

A review of the literature on awareness, attitudes and behaviours of stakeholders regarding the use of bio-based fertilisers made it possible to identify factors that have a significant impact on the opinion of the main stakeholders on fertilisers from waste. Barriers identified for the farmers, customers and producers through a literature review are presented in Table 36, 37 and 38.

Table 36. Barriers identified for the farmers through a literature review

Barriers		
Aspect	Description	Reference
Health risk	It is a well-known fact that animal manure is rich in nutrients and can be used to facilitate the plant growth. However, similar to other bio-based fertilisers some of their limitations are also associated that increase the risks on the safety of the consumers, physiochemical and biological stability of the soil. The higher content of ammonia present in the manure burns plant roots and foliage, together with increasing the transportation cost and weed production.	(Ajmal et al., 2018; Chen et al., 2018; Perdana et al., 2018)
Heavy metal content	The bio-based fertilisers can be rejected or accepted according to the level of its hazardous characteristics like corrosively, reactivity, toxicity, flammability and other biological hazards. Bio-based fertilisers such as sewage sludge and sewage sludge ash need to be almost free from heavy metals and need to be certified as safe and applicable. The sanitary conditions are meant to lessen the health risks to the human and the environment.	(Amann et al., 2018; Savci, 2012; U.S. EPA, 2019)

Reliability and efficiency	Chemical fertilisers give better results and are more reliable due to certain and stable nutrient content. Moreover, the majority of chemical fertilisers are certified and undergo precise laboratory tests.	(Nobile et al., 2020; Pacheco et al., 2017; Romanenkov et al., 2019; Vaneeckhaute et al., 2013)
Consumers' opinion	Research has shown that farmers in Vellore are concerned that consumers will not accept food fertilised with urine, only 25% of farmers have a different opinion. Some farmers claimed that they would not inform consumers about their practices. Farmers may not be aware of the fact that there is accreditation among consumers or do not believe in the positive effects of this practice.	(Simha et al., 2017)
Caste hierarchy in society and sanitation	In India as a whole, 'caste traditionalism' plays an important role in determining people's profession. By convention, the upper castes are 'landowners' who never work on the land, as manual labour is considered demeaning and best left to the lower castes excreta disposal are discriminated as 'polluting labour' and these activities are traditionally performed by the lowermost sections of Indian society. In the present survey, both the upper and lower castes seemed to agree that the use of urine on their farms would put them at risk of being ridiculed. It could be so that the position of upper caste farmers in society may create hesitation among them to considering using urine, whereas among farmers	(Simha et al., 2017)

	belonging to the lower castes a lingering fear of returning to their erstwhile unfavourable positions.	
Trust	Demography, culture and tradition significantly shape the approach and management practices. Vellore farmers, for instance, 'trust' could be a key variable that determines the proliferation potential of human waste recycling. Farmers in that region trust and value the opinions of people they know, people to whom they are related or people with whom they have been socialising and interacting over the years. In rural India, farmers have been observed to rely on the advice of people they know, family members and, in many cases, helpful neighbouring farmers, rather than 'expert' advice.	(Simha et al., 2017)
Public opinion	According to farmers, the main problem associated with the use of sewage sludge for fertilising crops is public opinion, because the success of sewage sludge depends on consumer satisfaction.	(Rashid et al., 2017)
Little contact with soil extension worker	Some of the farmers still lack information on technique, time, and proportion of organic fertiliser application, etc. It happened that farmers were relying on what their neighbours were practicing, thus explaining many imprecise methods observed. Therefore, the quality of techno-transfer and extension service given by agencies to rice farmers needs to be improved to better access relevant information of the farmers on the successful use of bio-based fertilisers.	(Chouichom and Yamao, 2011)

The high cost of the transportation	Usually, provinces use manure from their own animals, but the amount of manure is often not enough because farmers have very few animals. They must buy from their neighbours and some farmers bought manure from commercial farms, which are usually quite enough far. Therefore, the amount of fertiliser used by farmers may be limited due to concerns about high transport costs. Transport costs may decrease, due to the infrastructure and transport company's development.	(Chouichom and Yamao, 2011; Koelsch et al., 2020)
No need to use fertilisers	Some of the farmers feel that their crops grew well enough without using fertilisers, so there's no need to spend money on fertilisers.	(Dahlin et al., 2017)
Risk of extra work	Some farmers believe that the application of fertilisers will significantly accelerate plant growth, which will require additional work.	(Dahlin et al., 2017; Koelsch et al., 2020)
Uncertainty about nutrient content	One of the barriers identified by farmers was the uncertainty about the content of nutrients, which causes difficulties in planning and application.	(Bonnichsen and Jacobsen, 2020a)
Uncertainty about the efficiency	Some farmers are concerned that the new fertilisers will not be as effective, as synthetics.	
Slow nutrients release	Some farmers prefer fast-release, synthetic fertilisers, with immediate nutrients availability. Some crops have a high nutrient requirement, throughout all the growth cycle. In this case, slow-release fertilisers may not be effective. Farmers don't always understand that the immediate nutrients availability creates a risk of leaching.	(Case et al., 2017; Pampuro et al. 2018; Koelsch et al. 2020)

Unpleasant smell	A very important identified barrier to the use of bio-based fertiliser was odour for neighbours.	(Bonnichsen and Jacobsen 2020; Case et al. 2017; Koelsch et al. 2020)
Limited availability	Some farmers are willing to use bio-based fertilisers, but they don't have access to it, for various reasons (mainly due to the irregular distribution of livestock farms).	(Case et al., 2017)
Aversion to changes	Elderly farmers are reluctant to change and do not trust new products.	(Bonnichsen and Jacobsen, 2020b; Case et al., 2017; Tur-Cardona et al., 2018b)
Soil deterioration	Bio-based fertilisers application can contribute to destruction of soil structure by longer application time and the heavy equipment.	(Case et al., 2017; Tur-Cardona et al. 2018; Koelsch et al. 2020)
Political conditions	Policies focusing on the surpluses reduction and restrictions on the use of raw organic waste cause, that they are not treated by farmers as a valuable secondary raw material.	(Bonnichsen and Jacobsen, 2020b; Koelsch et al., 2020)
Low environmental awareness	The survey shows that farmers are not guided by environmental concerns, choosing a fertiliser.	(Koelsch et al., 2020)
High initial costs	For farmers, the initial costs could be related e.g., to the purchase of equipment, for the specific form of fertiliser application.	(Koelsch et al., 2020)

Lack of knowledge about bio-based fertilises effect	In a survey on the use of manure, it was found, that the information held by farmers was not correct. Educational programs must be implemented, that to make it possible for farmers to make decisions based on facts, not on a misconception. Lack of knowledge about the fertiliser characteristics and effect may result in a lack of trust in the product.	(Koelsch et al., 2020; Pappalardo et al. 2018)

Table 37. Barriers identified for the consumers through a literature review

Barriers		
Aspect	Description	References
Price	Price is usually used as one of the main criteria for product selection. If a bio-based product is more expensive than a conventional product, there is a risk that consumers will choose a cheaper product.	(Laborda et al., 2023)
Availability	People are eager to find products in their local stores, but prefer to do simple shopping without having to spend too much time evaluating which option is best There is a risk that consumers will not want to buy a product that is not available in their local stores.	(Laborda et al., 2023)
Information on the product regarding CE and safety of use	According to consumers, it is necessary to provide clear information on how a bio-based product effectively addresses issues related to circularity and safety.	(Laborda et al., 2023)
Aesthetics	A factor that can influence the purchase decision is aesthetics, which can be a significant barrier for some consumers.	(Laborda et al., 2023)

There is limited research on barriers to the use of agricultural products and food produced with bio-fertilisers by consumers. On the one hand, the farmers are concerned about the consumers attitude to this type of product, and they are reluctant to admit use bio-based fertilisers. The risk of an increase in the prices of food products related to the costs of waste processing and a possible reduction in yield, may be a problem in the future introduction to the market of bio-based fertilised crops. On the other hand, growing ecological awareness and more and more frequent attention to product quality, not only to its price, may constitute an opportunity to successfully promote such products.

Table 38. Barriers identified for the fertiliser's producers through a literature review

Barriers		
Aspect	Description	References
Legal limitations	Various legal frameworks towards using waste-based fertilisers have been developed in many countries. The main barriers stopping from application of bio-based fertilisers are bans put in many countries on direct application of many bio-based fertilisers, such as sewage sludge or sewage sludge ashes (incinerated sludge). Irrigation by using treated wastewater is also prohibited in many countries, while using human excreta is not even considered in legal terms. Moreover, more and more restrictive legal regulations regarding the permissible amounts of phosphorus, applied to the soil, may make it necessary, to adjust the composition of the produced fertiliser to the new limits.	(European Commission, 2000; Günther et al., 2018; Herzel et al., 2016)
Mutation during fermentation	During the fermentation process of bio-based fertilisers mutate what often results in the rise of production and quality control cost. There is a need to	(Ajmal et al., 2018; Waqas et al., 2019)

	give more attention to this aspect in order to eliminate such unwanted conditions.	
Unavailability of appropriate and efficient strains	The lack of effective strains is one of the most important flaws that make the bio-based fertilisers unfit for the crops and soil. The selected strains be compatible to different environmental conditions and should be able to survive in broths and inoculant carriers.	(Ajmal et al., 2018)
Unavailability of suitable carrier	Due to the unavailability of the suitable culture in which the bacteria grow and multiply itself, the bio-based fertilisers shelf life is restricted. Peat of good quality containing carbon content more than 75% is very rare. Since a good quality carrier should have a combination of various characteristics like moisture holding capacity, free of toxic substances and adjustable pH, finding such carrier is not an easy task.	(Adam et al., 2009; Ajmal et al., 2018)
Lack of expertise and knowledge	The personals responsible for the sales of the bio-based fertilisers are not aware of the proper inoculation techniques. Since these products contain living organisms, their handling, transport and storage is not very easy to manage. Therefore, the lack of expertise and the level of uncertainty in this field give rise to complications.	(Ajmal et al., 2018; Günther et al., 2018)
High initial costs	The lack of government financial incentives could prevent companies from starting the bio-based fertilisers producing, especially in view of the low prices of fossil fuels.	(Bencheva and Tepavicharova, 2017; Santagata et al., 2021)
Financial analysis need	Conducting a financial analysis of the implemented solution is the basis for determining, whether a given	(Santagata et al., 2021)

	recovery method turns out to be profitable - without implementation examples, a detailed analysis is difficult to carry out.	
Diversified form and composition of recyclable materials	Large diversification of raw materials, e.g. in terms of the content of water or nutrients, generates the need for appropriate preparation of the material and adaptation of processing methods and installations.	(Santagata et al., 2021)
The high cost of the transportation	In some countries, nutrient recovery facilities are often located far from secondary raw material sources.	(Santagata et al., 2021)
Low pH of some wastewater	The low pH of some wastewater (e.g., acidic air scrubber water) can cause corrosion of plant installation components and acidification of the final product. To prevent of ammonia emissions and to reduce health risks, pH neutralisation is required. Storage or mixing (with alkaline wastewater), acid streams may also emit hydrogen sulphide.	(Vaneeckhaute et al., 2013)
Waste landfilling	Landfilling of biodegradable waste causes a loss of nutrients and reduces the amount of recyclable material, to biogas or bio-based fertilisers production.	(Bencheva and Tepavicharova, 2017)
Low willingness-to-pay	The research shows, that farmers may not be willing to pay for bio-based fertilisers a price, that will cover the cost of production and ensure a profit for the producer.	(Bonnichsen and Jacobsen, 2020b; Tur-Cardona et al., 2018b; Hills et al. 2021)

No analysis of on consumer opinions on food, or agricultural products made with the use of bio-based fertilisers has been found in literature reports. On the one hand, the farmers are concerned about the consumers attitude to this type of product, and they are reluctant to

admit use bio-based fertilisers. The risk of an increase in the prices of food products related to the costs of waste processing and a possible reduction in yield, may be a problem in the future introduction to the market of bio-based fertilised crops. On the other hand, growing ecological awareness and more and more frequent attention to product quality, not only to its price, may constitute an opportunity to successfully promote such products.

Drivers to the use of bio-based fertilisers

Drivers identified for all of the stakeholder's groups, through a literature review arer presented in Table 39.

Table 39. Drivers identified for all of the stakeholder's groups, through a literature review

Drivers			
	Aspect	Description	Reference
Legal	Legal regulations imposed on the use of chemical fertilisers	The risk of eutrophication has brought to attention the rising problem of extensive usage of mineral fertilisers which in many regions is the biggest source of nutrients which can accelerate eutrophication. Therefore, many countries have imposed legal limitations on the quantity, application method, storage, etc. of mineral fertilisers.	(European Commission, 2019, 1991; U.S. EPA, 2019)
Environmental; Social	Growing need for sustainable fertilisers	Due to the current trends in the public relations of many leading companies related with positive ecologically sounds appearance fertilisers producers are trying to promote their products as sustainable. Therefore, there is a high need for agricultural product that does not leave any harmful residue or pollutants in the environment and gives organic products.	(Kok et al., 2018; Pahl-Wostl et al., 2003)

Social	Customer demand and market size	The growing demand for "bio" products keeps stimulating the market of bio-based fertilisers. However, their production needs to ensure a return from the investments made to produce the bio-based fertiliser in a reasonable period of time. Some studies show interest in fertilisers from waste among farmers.	(Andrews and Tommerup 1995; Martínez et al. 2017; Bencheva and Tepavicharova 2017)
Economic	Increasing costs of mineral fertilising agent's extraction (e.g. phosphate rock)	Phosphate fertilisers are mined from only a few rock phosphate deposits in the world and the peak of extraction of phosphate is expected to happen in the 2030s with the prices expected to increase afterwards due to the higher extraction cost.	(Cordell et al., 2009; Rashid et al., 2017; Smol, 2019)
Economic	Exchange between farmers	Some European farmers have agreements between neighbouring farmers to distribute their manure. This allows for easy and efficient use of animal waste in the fields.	(Bonnichsen and Jacobsen, 2020a)
Social	Consumers' opinion	According to research, there are signs that consumers can accept this food fertilisation system. To introduce such a fertilisation system, it is necessary to show farmers that consumers are willing to buy products fertilised with human urine. Consumers in urban, semi-urban and eco-housing estates have said that there is a high acceptance of urine discharge toilets and the reuse of human waste for food production.	(Simha et al., 2017)

Technological; Economic	The possibility of combining sectors	The possibility of combining production with energy recovery, gives the opportunity to reduce costs of fertiliser production and to obtain additional financial benefits from their sale, especially that the processes use low-cost materials (waste). Fertiliser production can accelerate the initial costs recovery and enable new investments.	(Pappalardo et al., 2018; Santagata et al., 2021)
Technological	Technological progress	The multitude of raw materials and the need to improve technological processes in the field of obtaining fertilisers and energy from waste generate technological progress.	(Santagata et al., 2021)
Social; Economic	Availability of information	The availability of information about the product causes an increase in interest and willingness-to-pay.	(Koelsch et al., 2020; Pappalardo et al., 2018)

Benefits to the use of bio-based fertilisers

Benefits, identified for all of the stakeholder's groups, through a literature review are presented in Table 40.

Table 40. Benefits, identified for all of the stakeholder's groups, through a literature review

Benefits			
	Aspect	Description	Reference
Environmental	Relatively lower environmental impacts	Due to high availability for plants, the bio-based fertilisers are immediately absorbed by plants and are not vulnerable to be flushed with the surface runoff to surface waters causing eutrophication.	(Carpenter et al., 1998; Poikane et al., 2019; Wojciechowska et al., 2019)
Environmental	Renewable resource	The use of bio-based fertilisers is considered as a good practice while the deposits of mineral biogenic raw materials such as phosphorus is limited and non-renewable.	(Chojnacka et al., 2020; Nesme and Withers, 2016)
Technological	Easier processing	Bio-based fertilisers are in general easier to process which generally comprise of pulverisation, neutralisation, sterilisation, packaging and transport.	(Ajmal et al., 2018)
Economic	Economic factors	The application of bio-based fertilisers is often characterised by lower transport and production or purchase costs.	(Chojnacka et al., 2020; Supaporn et al., 2013)
Economic	Decreasing amount of insect and pests	Regarding farmers' opinions about organic fertilisers it was also noticed that when they use organic fertilisers, the number of pests and insects in the farm area decreased.	(Chouichom and Yamao, 2011)

Economic	Independency from foreign supplies	By using locally produced bio-based fertilisers the framers are independent from foreign mineral fertilisers producers.	(Hamilton et al., 2017; Müller et al., 2007)
Environmental (also, Economic)	Improvement of soil structure	Many farmers cited improved soil structure as one of the greatest advantages of using bio-based fertiliser. Higher organic matter content in bio-based fertilisers, has a positive effect on soil structure (e.g. some digestate fertilisers has higher C/N ratio, then manure).	(Vaneeckhaute et al. 2013; Case et al.2017; Tur-Cardona et al. 2018; Pampuro et al. 2018; Bonnichsen and Jacobsen 2020)
Environmental; Legal	Lower phosphorus pollution	The use of liquid digestate as fertilisers may be a solution to the problem of exceeding phosphorus limits, as this element accumulates mainly in the thick fraction (the liquid fractions have a higher N/P ratio).	(Vaneeckhaute et al., 2013)
Environmental	Climate change mitigation	The use of BBFs as organic fertilisers has some advantages in adapting to the effects of climate change, as it has a higher water retention capacity than mineral fertilisers.	(Kurniawati et al., 2023)

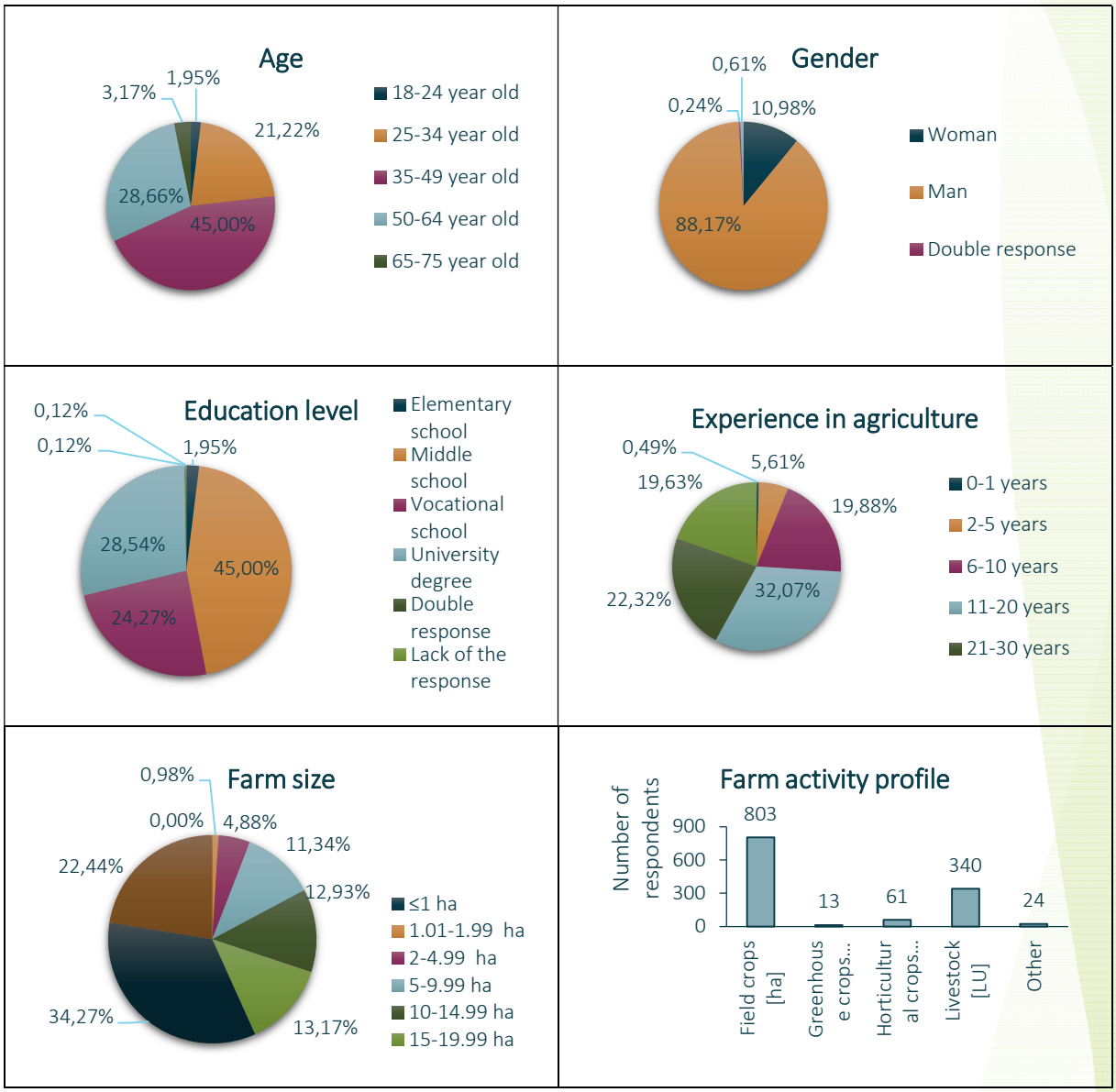
Summary of literature review

The study findings could inform customer prospecting and segmentation, mainstreaming of policies and awareness campaigns, as well as targeting innovative farmers to champion on-farm demonstration trials in development practice. From the analysis of the identified barriers it seems that legal limitations are the biggest concern of farmers, especially in developed western countries. The situation in developing countries from Asia and Africa is different while they often face technical and habitual or cultural difficulties with using bio-based fertilisers. Therefore, education and promotion regarding the using alternative fertilisation methods is needed to introduce more sustainable agricultural practices in those regions. The barriers identified mainly in European countries, are largely related to the reluctance, or lack of access to fertilisers from waste, also the technological or legal limitations, related to the processing, sale and use of bio-based fertilisers. According to the investigated cases of using bio-based fertilisers, the main drivers to change conventional fertilisation to waste-based products such as treated sewage sludge or wastewater were the customers demand and market conditions related with the growing popularity of "bio" or "organic" products. On the other hand, legal regulations - mainly limitations put on mineral fertilisers are efficient in supporting the use of bio-based fertilisers. An incontestable benefit resulting from the application of bio-based fertilisers are lower environmental impacts including soil but also water ecosystem (due to higher bioavailability of bio-based fertilisers the surface flow loads of nitrogen and phosphorus compounds are lower). Moreover, the use of bio-based fertilisers is in line with the circular economy assumptions, while waste is converted to fertilisers and are kept in the economy longer. This also contributes to economic benefits, while by using bio-based fertilisers the farmers reduce the need to buy and import mineral fertilisers. Furthermore, bio-based fertilisers are a renewable source of nutrients so, even if limited reserves of critical raw materials for agriculture (e.g. phosphorus) will end, the agriculture sector will be able to survive by using locally produced bio-based fertilisers. The information obtained through the research, carried out for the purposes of this report, served as the basis for conducting a survey among various stakeholders (farmers, consumers, producers), in order to determine their attitude and to assess their preferences regarding the characteristics of bio-based

fertilisers. The key insight is that environmental awareness may not have enough impact on the marketing of bio-based products.

Trial survey

The largest group of respondents consisted of farmers aged 35-49, comprising nearly half of all participants. Farmers aged 50-64 and 25-34 were also well-represented. Most participating farmers were men, although five respondents provided dual responses indicating both male and female genders. This is likely because these farms were jointly managed by both a man and a woman, such as married couples, who completed the questionnaire together. Approximately 45% of respondents had completed secondary education, while nearly one-third held higher education degrees, and around one-fourth had graduated from vocational schools. Moreover, most of the respondents have over 11 years of experience in agriculture (74.02%), with more than 32% of respondents having 11-20 years of experience. The research sample was predominantly composed of farms ranging from 20 to 49.99 hectares in size, although larger farms were also represented. Notably, none of the respondents were farmers managing farms measuring 1 hectare or smaller. Furthermore, the average farm sizes for each voivodeship were calculated based on the precise areas provided by farmers in open question. In terms of average farm sizes measured in hectares, it can be concluded that Dolnośląskie, Zachodniopomorskie, and Lubuskie voivodeships had the largest farms among the research sample. On the other hand, Małopolskie, Podkarpackie, and Świętokrzyskie voivodeships had the smallest average farm sizes (Figure 4). The farm's activity profile was determined through a multiple-choice question. Most farmers were engaged in field crop production. Additionally, a significant number of respondents also practiced animal husbandry, but in all cases, it was considered as an additional activity. Farmers involved in livestock breeding also conducted some form of plant production. For those who selected the "other" option, the most mentioned activities were permanent grassland (9 mentions) and beekeeping (4 mentions). Regarding the implementation of on-farm rotation strategies, nearly 93% of farmers confirmed its usage. Slightly over 6% of respondents reported not using such a strategy. Additionally, eight farmers responded with "I don't know," and one farmer did not provide an answer to the question (Figure 4).


Age
3,17%
1,95%
21,22%
28,66%
45,00%
18-24 year old
25-34 year old
35-49 year old
50-64 year old
65-75 year old
Gender
0,61%
0,24%
10,98%
88,17%
Woman
Man
Double response
Education level
0,12%
0,12%
1,95%
28,54%
45,00%
24,27%
Elementary school
Middle school
Vocational school
University degree
Double response
Lack of the response
Experience in agriculture
0,49%
5,61%
19,63%
19,88%
22,32%
32,07%
0-1 years
2-5 years
6-10 years
11-20 years
21-30 years
Farm size
0,98%
0,00%
4,88%
11,34%
22,44%
12,93%
34,27%
13,17%
≤1 ha
1.01-1.99 ha
2-4.99 ha
5-9.99 ha
10-14.99 ha
15-19.99 ha
Farm activity profile
Number of respondents
900
600
300
0
803
13
61
340
24
Field crops [ha]
Greenhouse crops...
Horticultural crops...
Livestock [LU]
Other

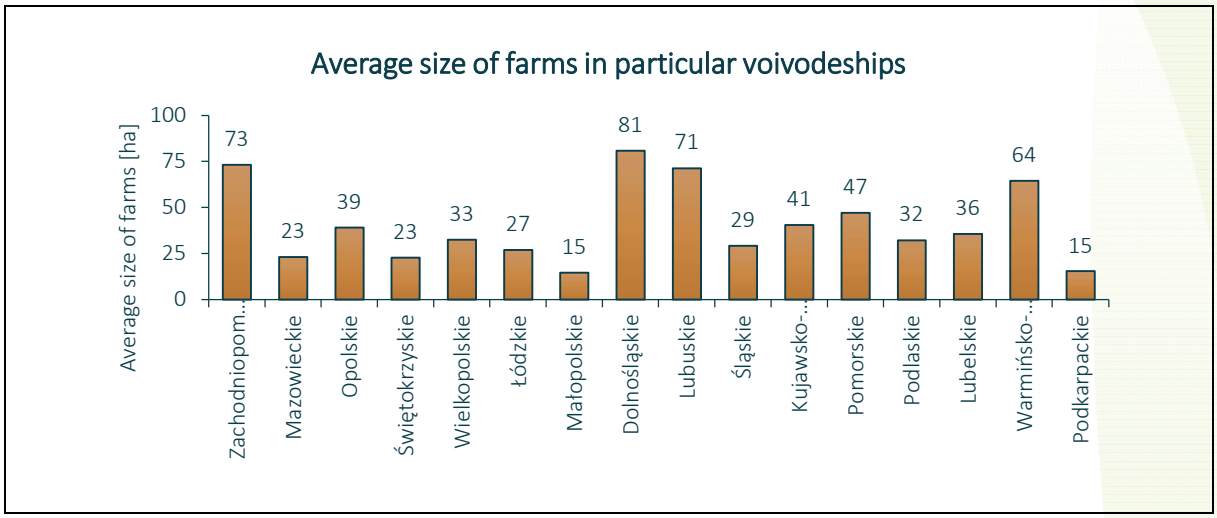


Figure 4. Basic characteristic of respondents and farm types.

Subsequently, the participants were asked to respond to a multiple-choice question regarding the type of fertiliser application equipment they possessed. Out of the total respondents, 698 reported having some form of fertiliser application equipment. The responses indicate that most farmers possess at least one type of applicator. Over half of the respondents own a soil applicator specifically designed for liquid fertilisers, while slightly fewer respondents possess applicators for solid fertilisers (Figure 5).

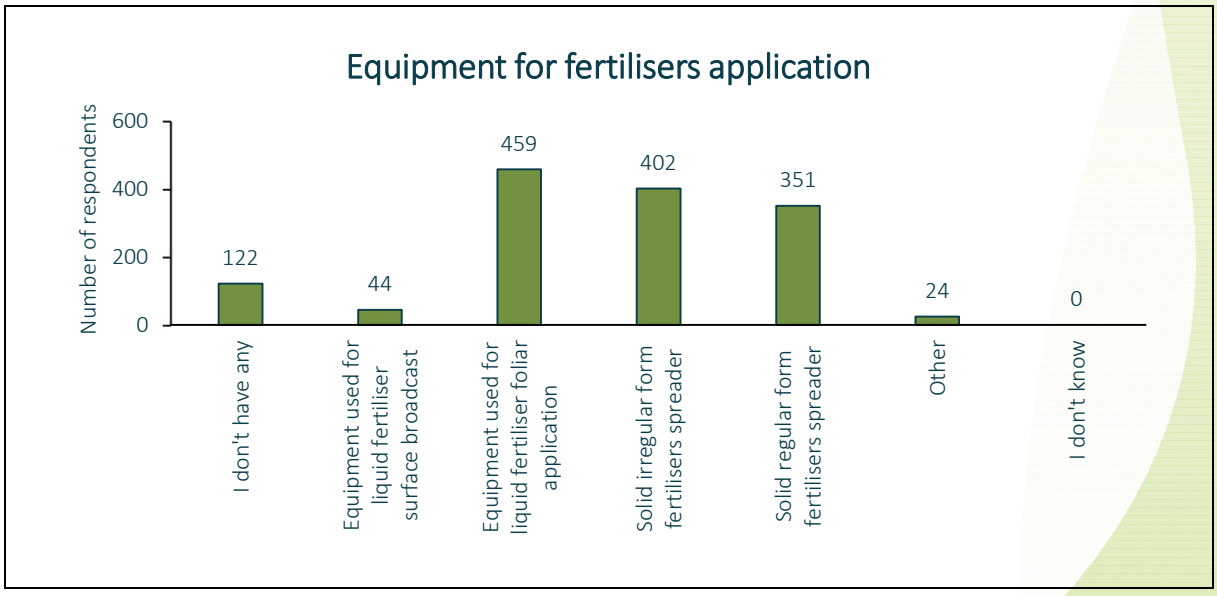


Figure 5. Equipment for fertilisers application, owned by respondents.

Followingly farmers proceeded to answer a series of single-choice questions (question 4-11) that provided further insights into the activities conducted by the respondents and the types of fertilisation methods they employed. Only 7.32% of the respondents reported engaging in organic farming practices. Additionally, less than 69% of farmers had a nitrogen fertilisation plan for their farms, and over 38% of respondents did not conduct analyses to determine the content of basic nutrients (nitrogen, phosphorus, potassium) before devising their fertilisation strategies. However, a significant majority of farmers (90.37%) claimed to consider soil quality or environmental conditions when planning their fertilisation strategies.

Most farmers (91.83%) implemented activities aimed at enhancing soil quality or fertility during their agricultural practices. Participants were also asked if they observed a decline in productivity within a specific area, unrelated to weather conditions. 12.44% of respondents answered, "I do not know," while the remaining farmers had divided opinions: 44.02% experienced a decrease, while almost an equal number (43.54%) reported no decline. Despite only 44% of farmers experiencing productivity declines, 59.02% stated that they felt the need to increase NPK dosages in their areas and only 37% declared no such necessity. Nevertheless, most farmers expressed satisfaction with the yields achieved in the previous year. Specifically, 710 farmers were content with the crop quality (responding with "yes" or "rather yes"), and 681 gave similar answers regarding crop quantity. According to the survey data, over half of the farmers (58.54%) encountered challenges with fertiliser availability during their agricultural activities.

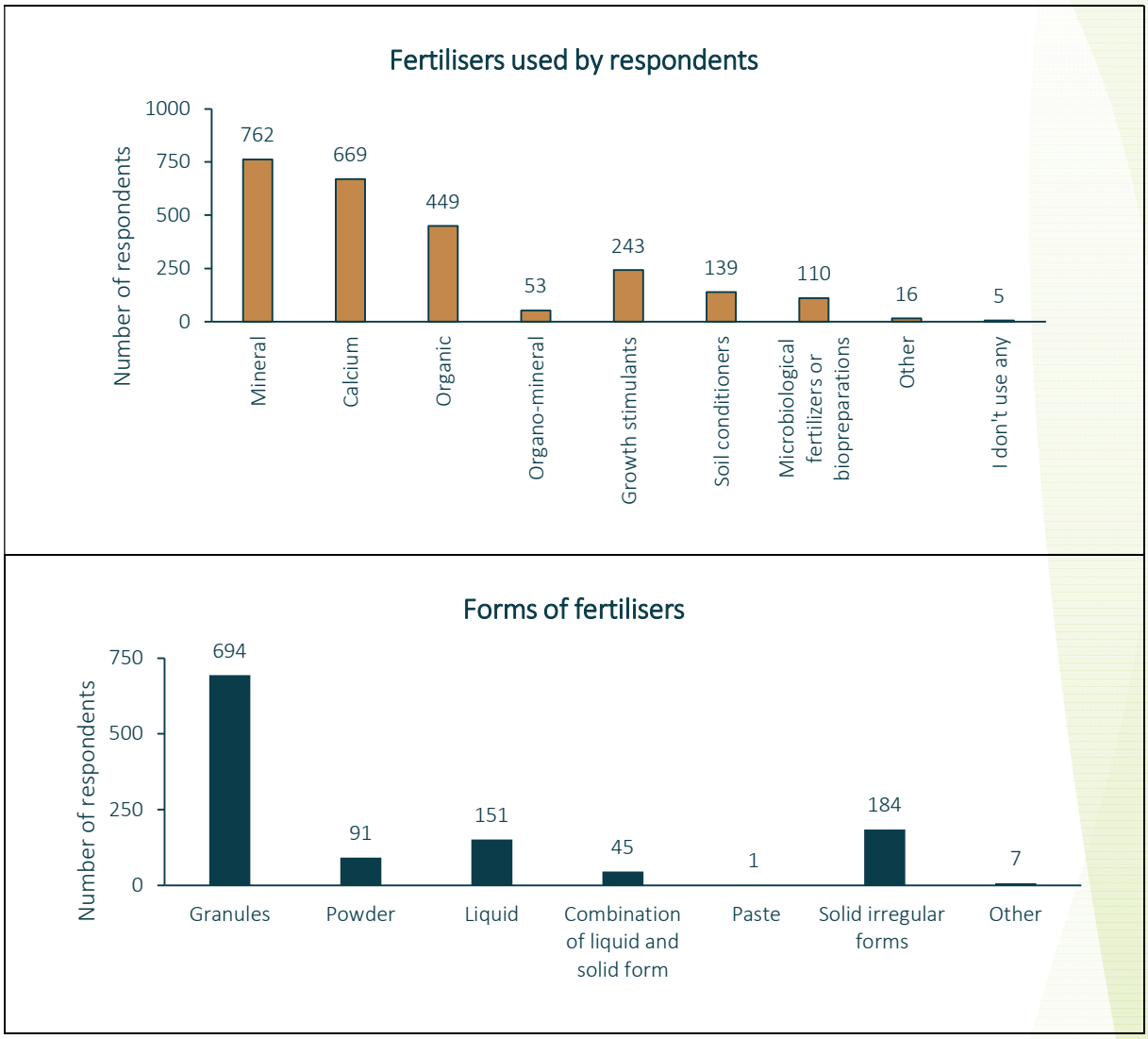


Figure 6. Types and forms of fertilisers used by respondents.

Question 12, which was multiple-choice and closed-ended, focused on the types of fertilisers used by farmers. The research sample overwhelmingly indicated mineral and lime fertilisers as the most commonly used. More than half of the respondents reported using organic fertilisers. Only five surveyed farmers did not utilise any fertilisers. Granules are the predominant form of fertilisers used, with only 126 respondents not utilising granulated fertilisers. A considerably smaller number of farmers (184) used irregular solid forms, while others employed liquid (151 farmers) or powder forms (91 farmers). Among those who selected the "other" option, all seven individuals mentioned forms that could be classified under different categories (Figure 6).

Moreover, most farmers prefer to purchase fertilisers in large bags or securely sealed packaging, such as bags, buckets, or containers. Fertilisers bought without any packaging were less commonly chosen. Among those who selected the "other" option, some respondents mentioned buying fertilisers in reusable containers. A subgroup of 18 farmers reported not purchasing fertilisers at all. The product's expiry date was highlighted as primary, the most important information displayed on fertiliser packaging by most farmers. Over one-third of the respondents considered the product's registration number to be important, while approximately 30% paid attention to the quality mark or logo provided by the fertiliser certifying authority. Around 28.4% of respondents found the note about controlled release or prolonged action of the fertiliser to be significant. Only slightly over 10% of farmers took notice of prefixes like "ECO," "BIO," or "GREEN" in the name of the fertilising product (Figure 7).

The primary sources for purchasing fertilisers among the respondents are local sales points and distributors/sales agents. 235 respondents opt for ordering fertilisers through phone or online channels. A minority of farmers who do not purchase fertilisers rely on their own organic fertilisers or obtain them from other farms (Figure 7).

Nearly all of the farmers who took part in the survey utilised mineral fertilisers. Nitrogen and multi-component fertilisers were particularly prevalent among the respondents. The least commonly used type among the farmers was magnesium fertilisers, although a considerable number of farmers (37.68%) still incorporated this type of fertiliser into their practices. A significantly smaller proportion of respondents utilise organic fertilisers compared to the mineral ones. Among these, manure is the most employed organic fertiliser, utilised by 60.12% of respondents (Figure 8).

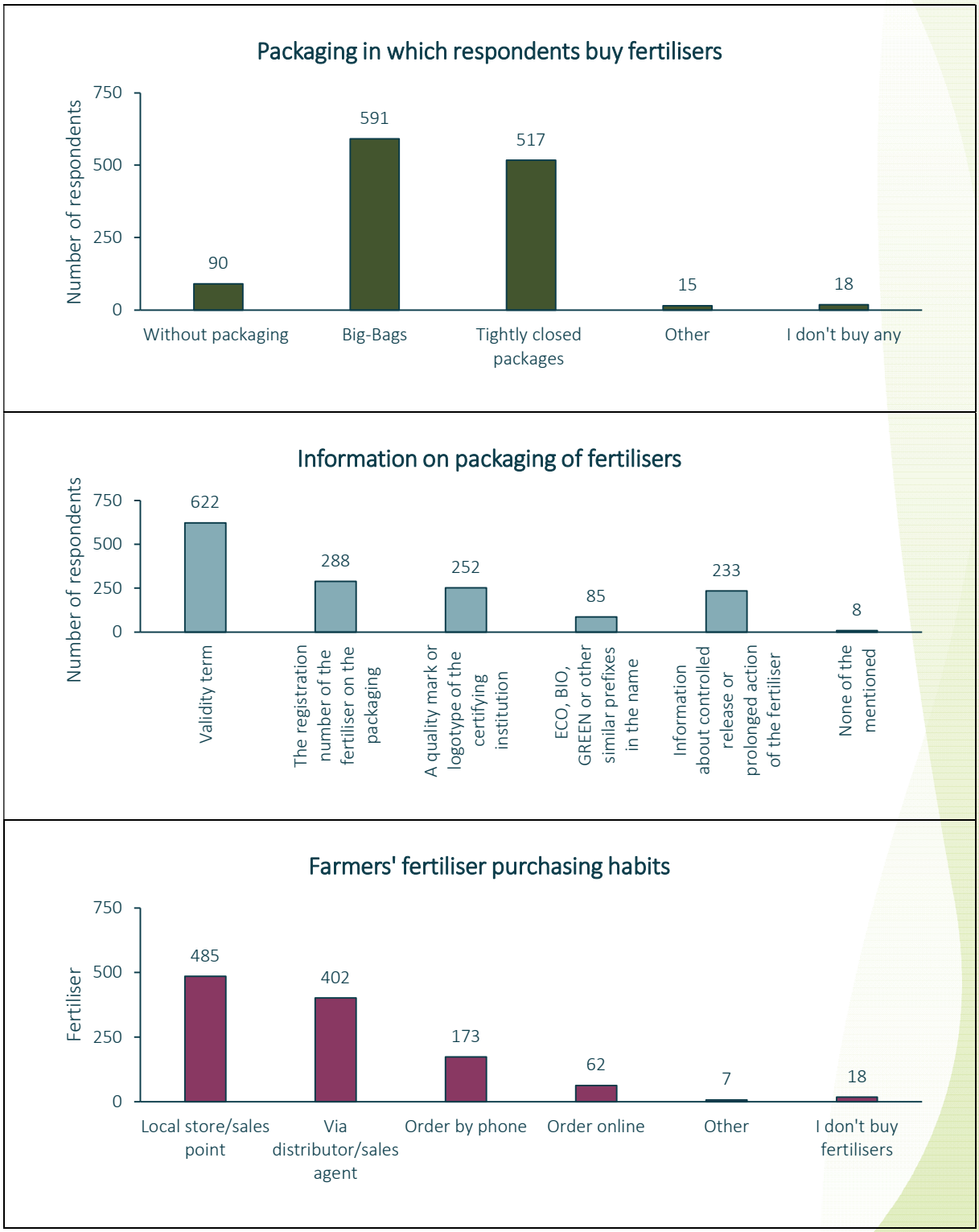


Figure 7. Packaging, relevant information on packaging, and places of buying of fertilisers.

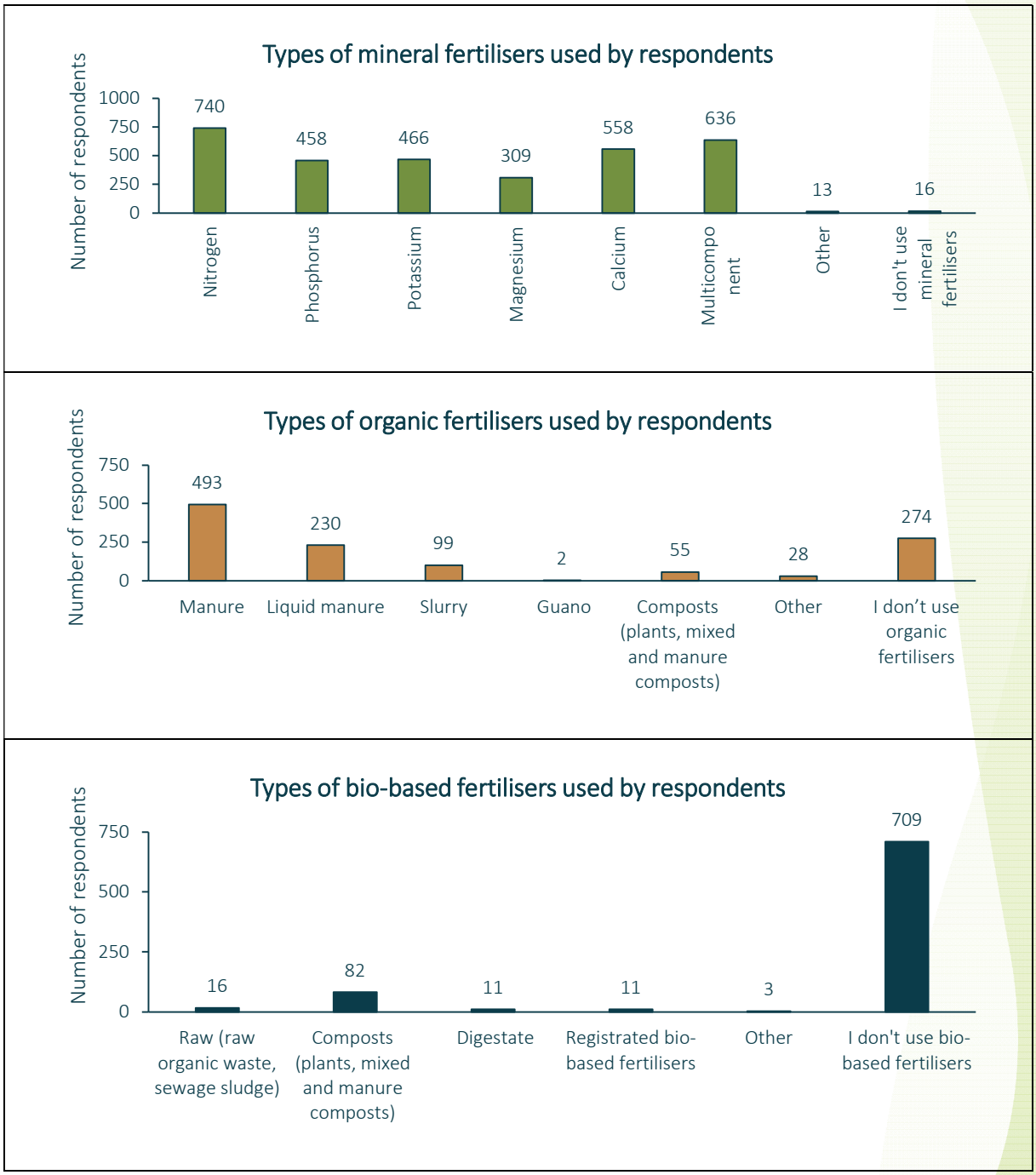


Figure 8. Types of mineral, organic, and bio-based fertilisers.

The survey data indicates that one-third of farmers do not incorporate organic fertilisers into their practices. Interestingly, the same farmers who reported using organic fertilisers also stated that they did not use BBFs, according to 709 respondents. It is noteworthy that the organic fertilisers mentioned in question 21 are also considered bio-based. 82 farmers

specifically mentioned compost as the bio-based fertilisers they used. In contrast, a smaller number of farmers mentioned raw waste, registered bio-based fertilisers, and digestate (Figure 8).

Questions 23-24 provided insights into the sources of organic fertilisers used by farmers. Half of the respondents (409 farmers) reported using their own organic fertilisers. Additionally, 99 farmers purchased registered organic fertilisers, while 65 respondents obtained such fertilisers from other sources, such as biogas plants. Nearly 50% of the organic fertilisers used by participating farmers were sourced from the same commune where their farms are located, as indicated by 409 respondents. This suggests that these cases involve the use of self-produced organic fertilisers. 78 farmers sourced fertilisers from the same countryside, 33 from the same voivodeship, and 16 imported fertilisers from more distant locations. Some farmers were unable to specify the origin of the fertilisers they used.

The overwhelming majority of farmers who reported using fertilisers derived from organic waste acquire them either on their own farms or from other units (questions 27-28). Merely 25 farmers purchase bio-based fertilisers. The majority of the fertilisers utilised originate from the same commune where the farms are located, while some are sourced from the same county. Only a small number of farmers rely on fertilisers transported over longer distances.

Subsequent questions (29-30) focused on evaluating the factors influencing the use of specific groups of fertilisers, with farmers providing assessments using a 5-point Likert scale. The assessments considered three categories of fertilisers: mineral, organic, and bio-based. Farmers were requested to provide responses for all types of fertilisers, even if they did not utilise them. Their evaluations could be based on theoretical knowledge, heard opinions, assumptions, or personal perspectives. The results for each factor were converted into percentages. The maximum rating for each factor was determined by multiplying the number of farmers who responded to the question by the highest possible score assigned to that factor. In practice, the maximum score was calculated as the number of farmers who answered multiplied by 5, resulting in 4100 points. The farmers' assessments of individual factors are depicted in the Figures 9-14.

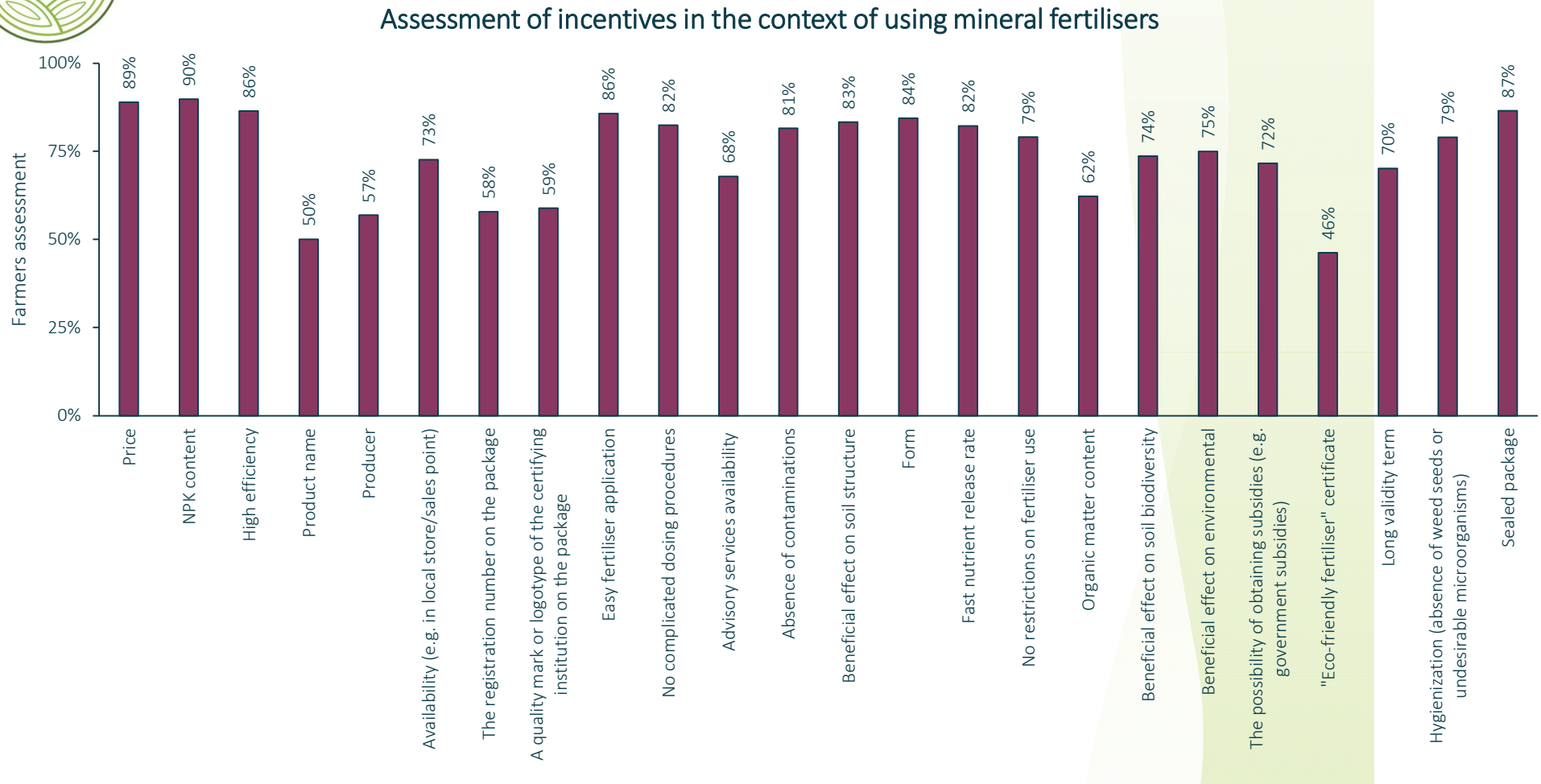


Figure 9. Assessment of incentives in the context of using mineral fertilisers.

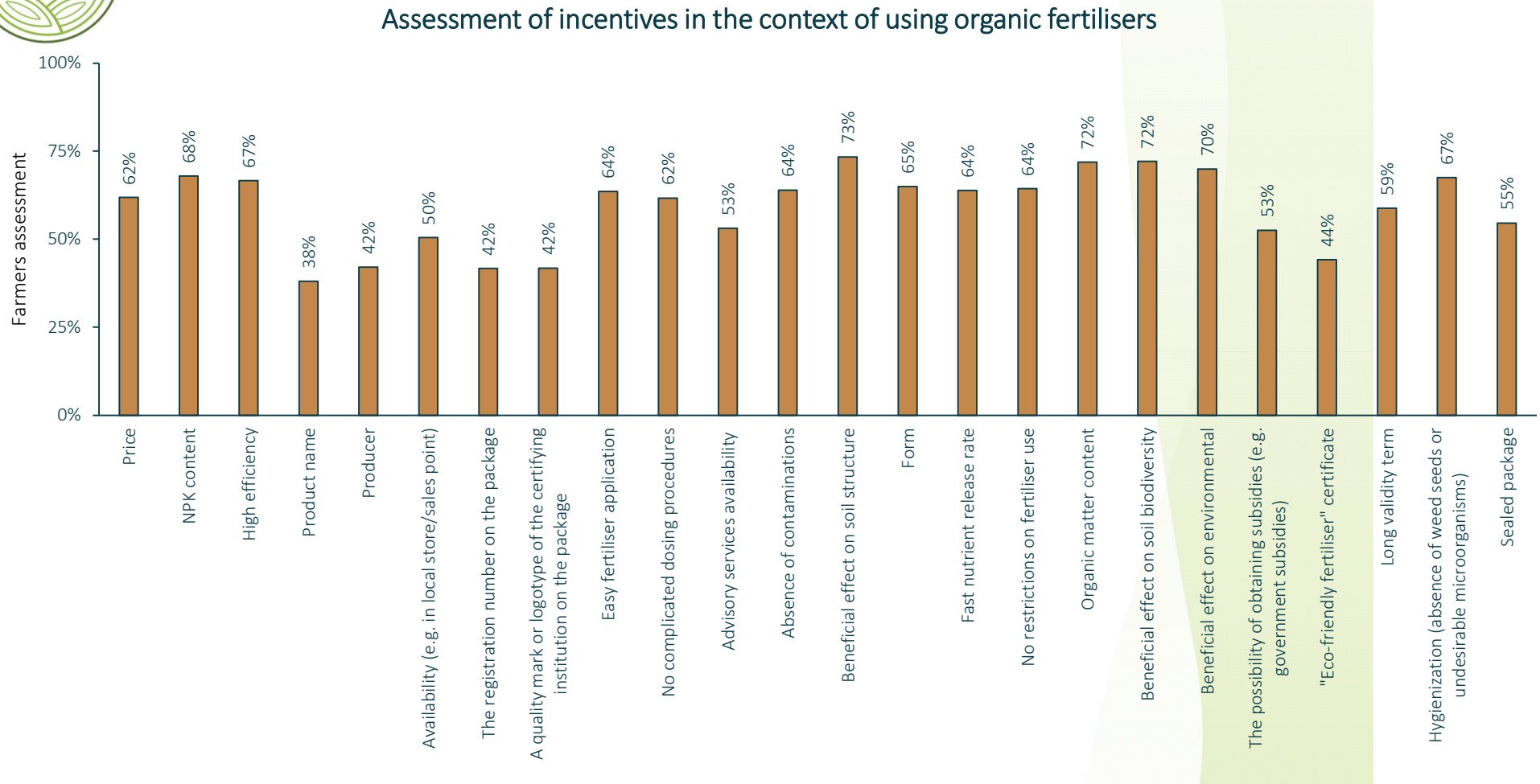


Figure 10. Assessment of incentives in the context of using organic fertilisers.

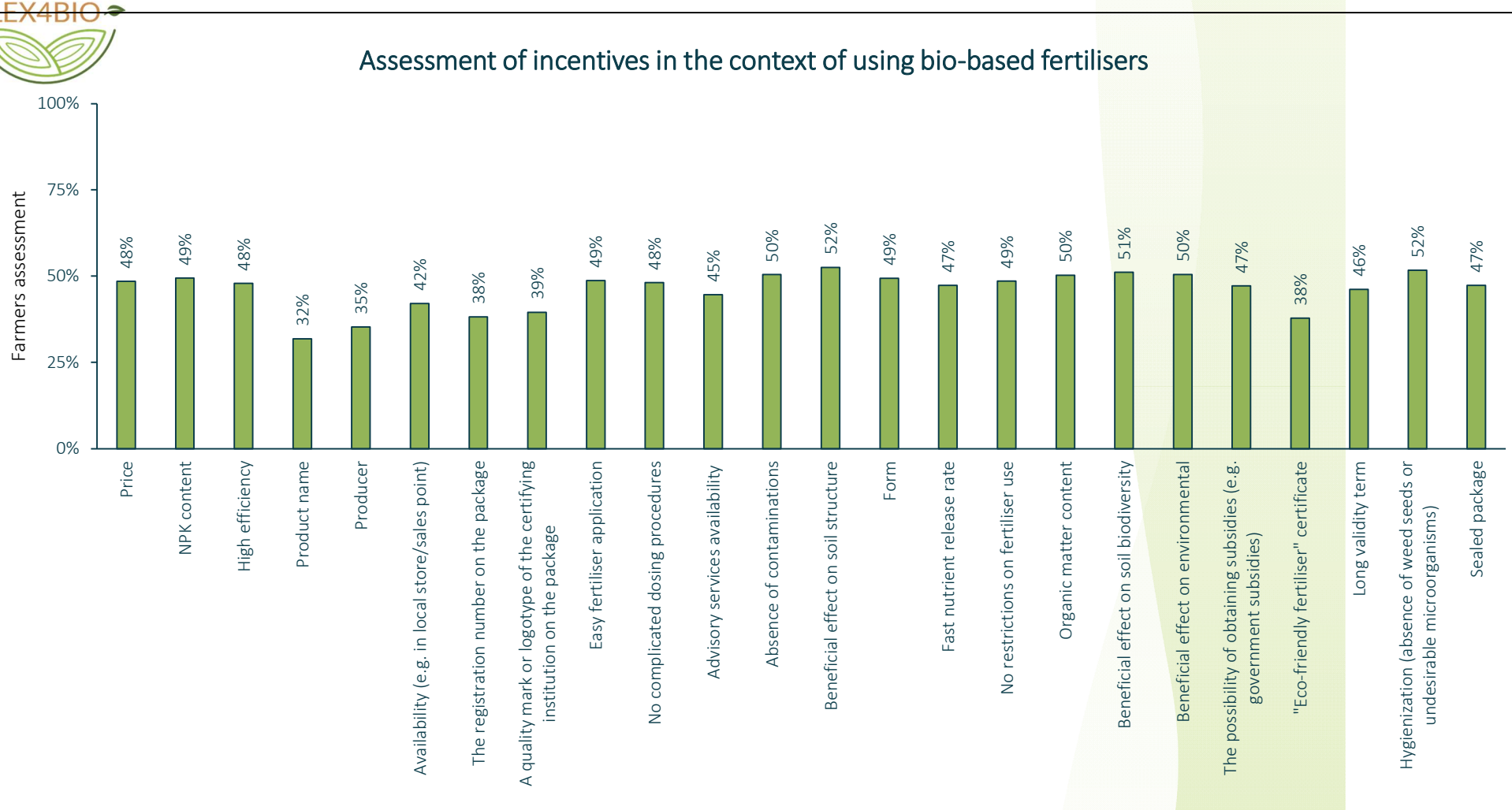


Figure 11. Assessment of incentives in the context of using bio-based fertilisers.

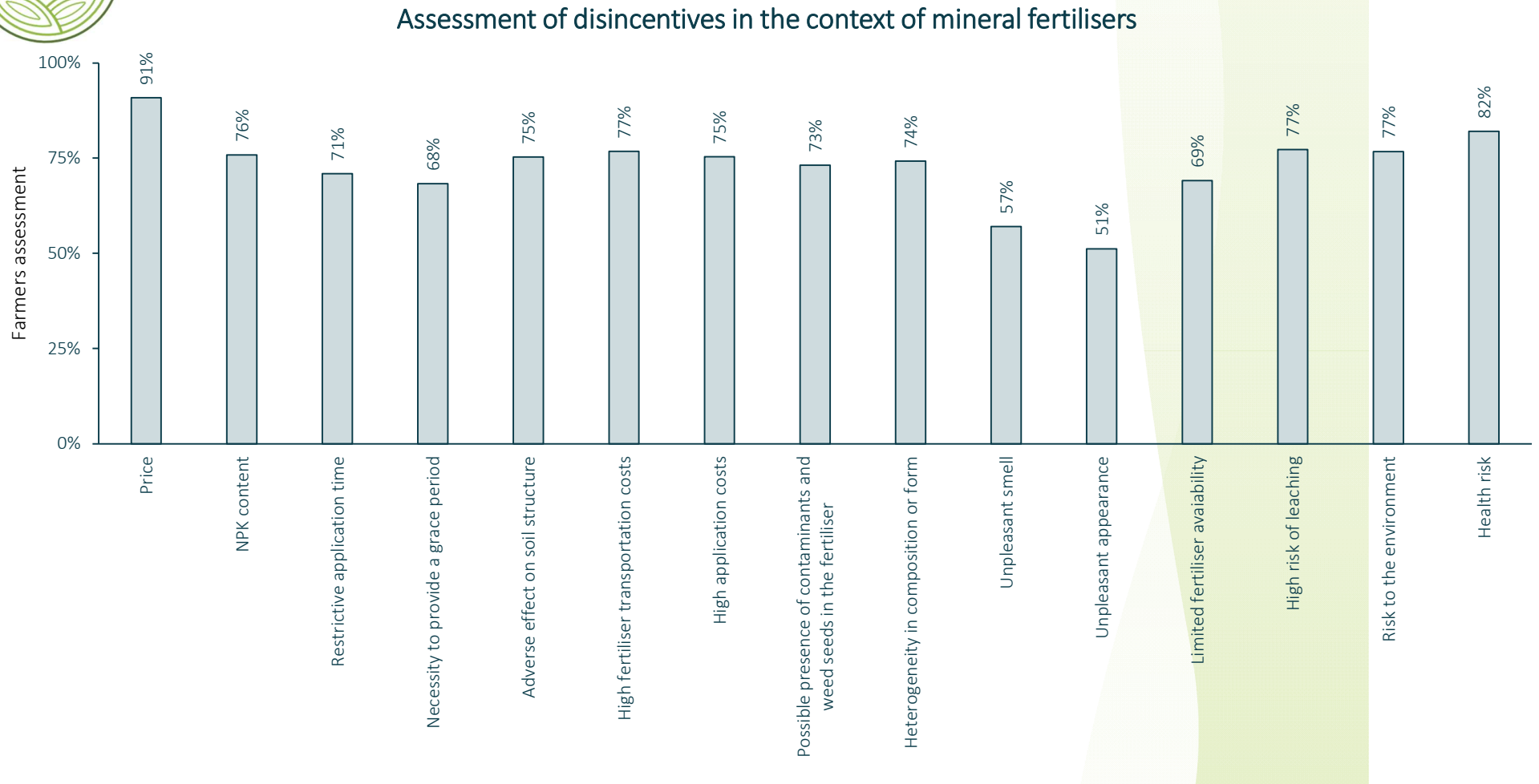


Figure 12. Assessment of disincentives in the context of mineral fertilisers usage.

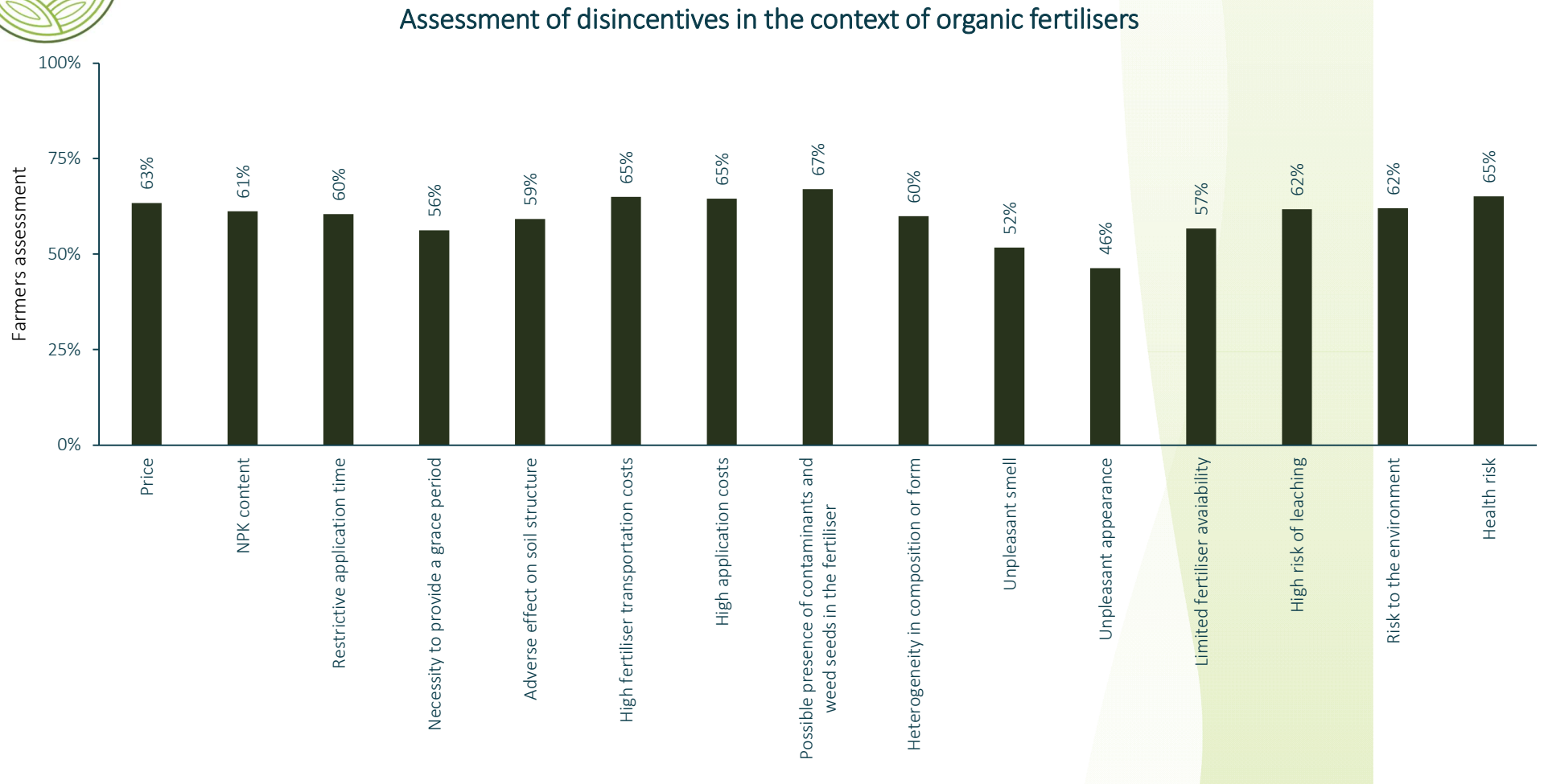


Figure 13. Assessment of disincentives in the context of organic fertilisers usage.

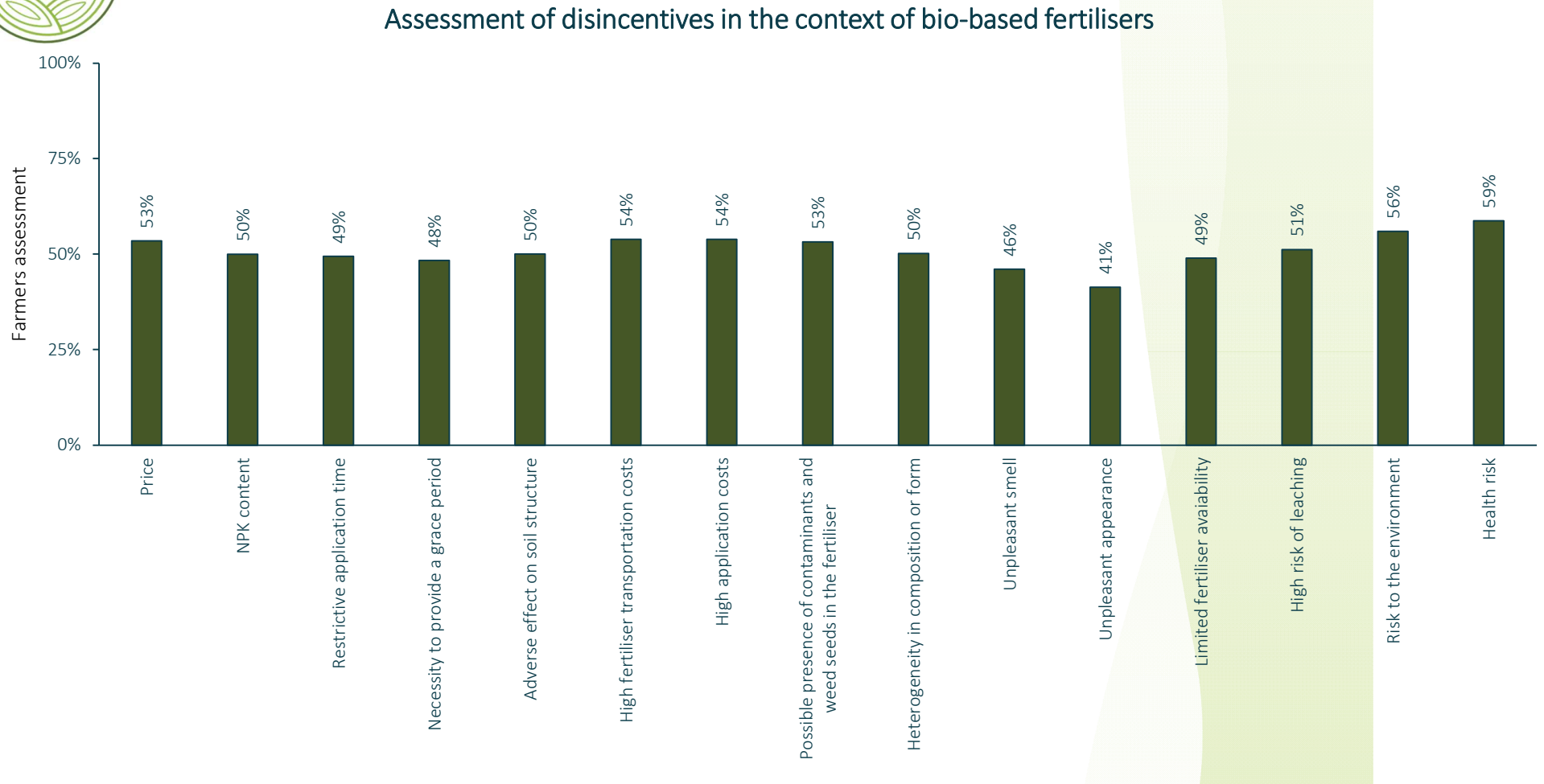


Figure 14. Assessment of disincentives in the context of bio-based fertilisers usage.

Mineral fertilisers received the highest level of incentives, as farmers considered the NPK content, price, and tightly sealed packaging to be the most advantageous features of this type of fertiliser. Conversely, features such as the "organic fertiliser" certification, name, and manufacturer of conventional fertilisers were deemed least encouraging by farmers. The presence of a registration number and the quality mark or logo of the certifying institution on the packaging also received low ratings. Organic fertilisers were ranked lower than mineral fertilisers, with the most encouraging features being their beneficial effects on soil structure, soil biodiversity, and organic matter content. The lowest-rated features aligned with those that farmers scored poorly for mineral fertilisers, with lower scores for each feature in the case of organic fertilisers. Bio-based fertilisers received the lowest ratings overall. The highest-rated feature for bio-based fertilisers, the beneficial effect on soil structure, was only acknowledged by 52.48% of farmers. Hygienisation, positive effects on soil biodiversity and the environment, absence of pollutants, and organic matter content were also assessed positively by over 50% of farmers. The least important feature, according to farmers, was the name of the product, receiving only 31.81% of the points (Figures 9-11).

When considering factors that discourage the use of fertilisers, price, the risk of health hazards, and the high risk of nutrient leaching from the soil were found to be the most important factors for mineral fertilisers. For organic fertilisers, farmers were most discouraged by the potential presence of contaminants and weed seeds, the risk of health hazards, and the high costs associated with transportation. Similarly, the risk of health hazards was the most significant factor deterring farmers from using bio-based fertilisers, followed by high transport and application costs. Across all groups of fertilisers, factors such as unpleasant appearance and smell were the least discouraging (Figures 12-14).

Question 32 evaluated if the selected prefixes would encourage respondents to purchase fertilisers. Approximately one-third of farmers expressed that the prefix "Bio" would be motivating for them, 26.34% of farmers found the prefix "Eko" encouraging, while a smaller percentage mentioned the prefixes "Green" and "REC". Half of the respondents (409 farmers) stated that none of these prefixes would persuade them to use a specific type of fertiliser.

The majority of respondents expressed a strong reluctance to increase the use of fertilisers derived from organic waste on their farms. Approximately 38.17% of farmers stated that they were not interested in increasing the use, while 29.63% replied that they rather did not want to increase their usage of this type of fertiliser. Only 13.42% of farmers indicated their willingness to use more bio-based fertilisers, providing "yes" or "rather yes" answers. However, over half of the farmers declared their willingness to partially replace their current fertilisers with organic alternatives. Out of the respondents, 205 answered "yes" and 258 answered "rather yes" regarding their willingness to make this partial replacement. On average, those who answered "yes" were willing to replace 55.54% of their current fertiliser with the organic equivalent, while those who answered "rather yes" were willing to replace 39.45%. In contrast, farmers showed less interest in replacing their current fertilisers with bio-based alternatives. Only 45 farmers declared their readiness for such a replacement, and 109 respondents indicated "rather yes". The average degree of declared replacement, expressed as a percentage, was 36.53% for those who answered "yes" and 28.88% for those who answered, "rather yes".

Respondents representing almost 85%, expressed the opinion that officially registered fertilisers should include information about their composition. Similarly, when specifically asked about bio-based fertilisers (BBFs), 88% of farmers argued that they should contain information regarding their composition. In a multiple-choice question regarding the preferred signage for BBFs, the respondents most indicated a "clear inscription on the label" (60.61%). A smaller number of farmers suggested that the appropriate form of labelling could be a "note to the name" (20.73%), a sign or symbol (19.02%), a specific colour of the packaging (17.32%), or an additional label information (11.59%). This information was deemed important by most respondents, as only 87 individuals selected the answer "does not matter." When asked about the most trustworthy form of information during the purchase, farmers indicated "a certificate issued by a national institution" (48.29%) as the best form. A significant portion (40.61%) also expressed their appreciation for information about test results confirming the safety of the product.

Slightly over half of the farmers did not have a specific opinion on the impact of organic waste fertilisers on crop quality and quantity. Regarding the effect on prices, 10.73% of farmers believed that the use of bio-based fertilisers would result in a decrease, while 12.44% believed it would lead to an increase in agricultural product prices. When considering the potential impact on crop quality, 18.17% of farmers believed it would be negative, while only 9.27% thought that waste fertilisers could improve crop quality. More than 35% of farmers expressed concerns that the use of bio-based fertilisers would discourage consumers from purchasing agricultural products. In terms of labelling, the majority of farmers (40.37% "yes" and 36.95% "rather yes") stated that agricultural products derived from crops fertilised with bio-based fertilisers should be properly labelled. However, only slightly over one-fifth (21.1%) of farmers claimed that their own choices were influenced by the decisions of their neighbours on this matter. Additionally, 54.27% stated that they were not influenced by their neighbours' decisions regarding the use of bio-based fertilisers.

The survey respondents identified livestock waste, specifically manure, as the most suitable raw material for producing bio-based fertilisers. Nearly 67% of farmers indicated manure as a suitable material. Plant agricultural waste was considered appropriate by over 58% of respondents. The other options received significantly fewer mentions, although respondents were allowed to select multiple types of waste. Only 18 farmers believed that none of the listed waste materials were suitable for fertiliser production.

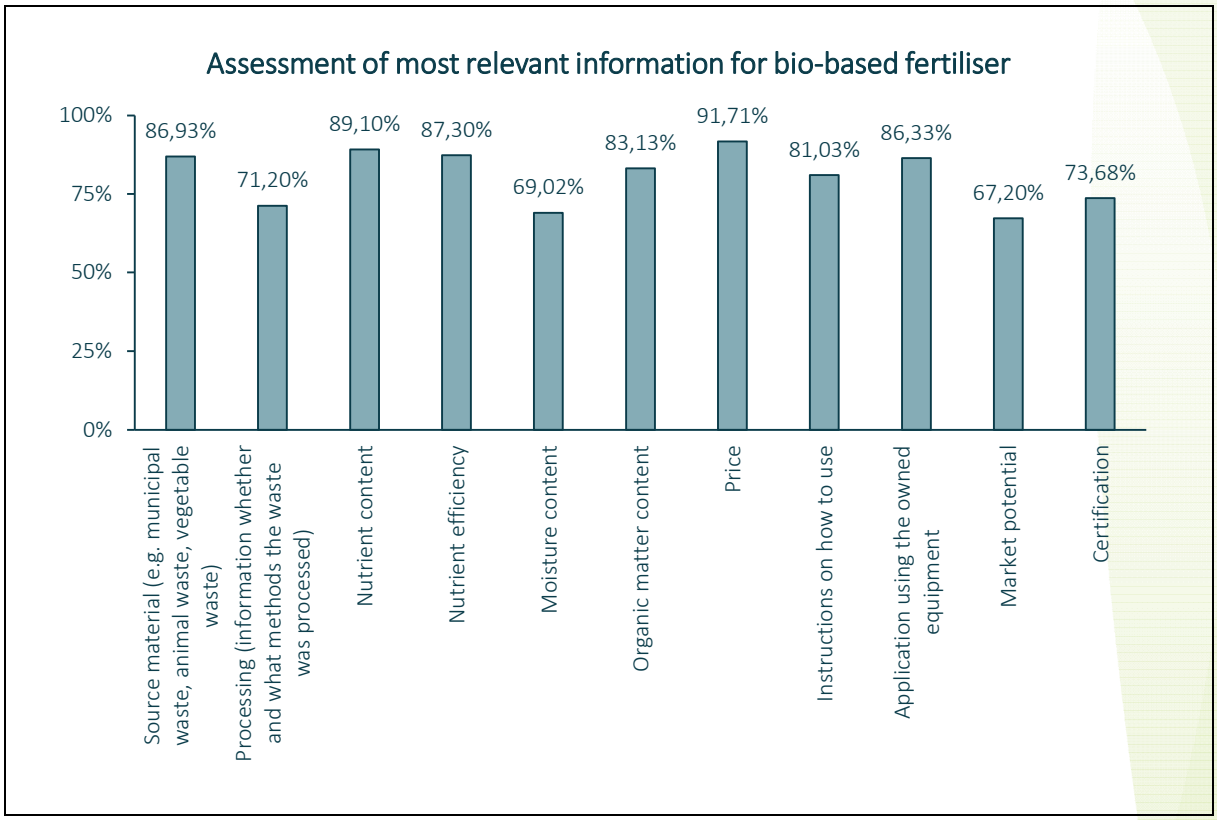


Figure 15. Assessment of most relevant information when choosing bio-based fertiliser.

In question 46, farmers were once again presented with a Likert scale and asked to assess the significance of different pieces of information when selecting a bio-based fertiliser. Respondents were allowed to choose multiple answers. The information about the price of the product received the highest rating. However, it is noteworthy that price is not among the highest-rated incentives for the use of bio-based fertilisers overall. Information about the nutrient content and effectiveness of the fertiliser was also highly valued. On the other hand, information about the market potential and moisture content were considered the least important, receiving ratings below 70% (Figure 15).

Most farmers expressed their willingness to purchase bio-based fertilisers if they had a positive impact on the environment or soil. A total of 529 farmers indicated their positive inclination, with 122 responding "Yes" and 407 responding "Rather yes". In contrast, only a small number of farmers (95 in total) stated that these properties would not serve as incentives for them to purchase waste fertilisers. Among them, 29 responded "No" and 66 responded "Probably no".

Questions 48 and 49 focused on determining the maximum prices farmers would be willing to pay for fertilisers that could fully meet the requirements of 1 hectare of crops. Question 48 did not provide any information about the type or origin of the fertiliser, while question 49 referred to an equivalent fertiliser produced from organic waste.

Farmers exhibited a higher willingness to pay for fertilisers without specified origin, as indicated in Table 41. The maximum price stated for the fertiliser in question 48 was 2.5 times greater than that offered for the bio-based fertiliser in question 49. It should be noted that this single value does not represent the opinions and preferences of the entire research sample and should not be regarded as a reliable parameter. Regarding the bio-based fertiliser, a larger portion of respondents chose not to declare any price, suggesting a lack of willingness to consider it as a fully valued product (no willingness to pay) or a disinclination to use it regardless of the price (no willingness to use). Furthermore, there were differences in the average price that respondents were willing to pay for fertilisers, with the average price for waste fertiliser being approximately 50% lower than that for the fertiliser in question 48.

Table 41. Comparison of prices that farmers would be able to offer for fertiliser from waste and analogous fertiliser without specified origin - maximum, minimum and average price.

Answers	Hypothetical fertiliser (question 48)	Analogous waste fertiliser (question 49)
Minimum offered price [PLN]	0	0
Maximum offered price [PLN]	15000	6000
Number of farmers who are not ready to pay for the fertiliser (PLN 0 answers)	17 farmers	72 farmers
Average [PLN]	938.46	654.54

The majority of respondents (55.12%) expressed a willingness to pay a higher price for the fertiliser mentioned in question 48. Only a small percentage of respondents (8.54%) valued the bio-based fertiliser higher. Approximately one-third of respondents (32.2%) indicated an

equal willingness to pay the same price for both fertilisers. However, the responses of 34 farmers (4.15%) did not provide enough information to make a price comparison (Table 42).

Table 42. Comparison of the willingness to pay for bio-based fertiliser and an analogous fertiliser without specified origin.

Number of respondents offering a higher price for fertiliser (question 48)	Number of respondents offering a higher price for fertiliser (question 49)	Number of farmers offering the same price for both
452	70	264

Table 43. Respondents' willingness the to pay for a fertiliser that have an additional feature.

An additional property of a fertiliser, with the primary feature as the supply of nutrients	Number of farmers who are willing to pay extra for a fertiliser with a given property (sum of answers "Yes" and "Rather yes")	Number of farmers who are not willing to pay extra for a fertiliser with a given property (sum of answers "No" and "Rather not")
Has a positive effect on the environment	57.93%	21.22%
Regulates the pH	84.63%	7.93%
Accumulates water in the soil	80.24%	8.42%
Accumulates nutrient in the soil	83.54%	6.46%
Has a positive effect on the soil microorganism’s growth	81.48%	6.22%
Has controlled release effect	68.9%	9.02%
Supply organic matter or huminic compounds	76.34%	7.07%
Prevents soil erosion	77.2%	10%

In the subsequent question, farmers evaluated the characteristics of fertilisers and indicated whether they would be willing to pay a higher price for a fertiliser that, in addition to providing nutrients, possesses one of the additional features (Table 43). The feature that received the highest willingness to pay from farmers was the ability to regulate soil pH. Additionally, many farmers expressed their willingness to pay extra for fertilisers that retain water and nutrients in the soil. On the other hand, the fewest number of farmers indicated a willingness to pay for a fertiliser that had a positive effect on the environment.

Final survey

Consumers

The largest portion of survey participants consisted of individuals between the ages of 25 and 40, making up over 40% of the total. There was also a significant representation of consumers aged 41-60. The majority of survey participants were female. Around half of the respondents had attained a college, bachelor's, or master's degree, or had even higher levels of education. Meanwhile, one-third of participants had completed secondary or high school. Approximately 10% of consumers had graduated from primary school, while 11% had completed vocational school. The distribution of respondents residing in villages and small cities with populations of up to 150,000 residents was relatively equal, ranging from 22% for cities with populations up to 50,000 residents to 26% for villages. The majority of survey participants reside in six specific countries, namely Germany, Spain, The Netherlands, Finland, France, and Denmark, with the number of respondents ranging from 53 to 58. In Poland, 38 consumers provided responses to the questionnaire, while in Austria, Hungary, Italy, Sweden, Lithuania, Latvia, and Belgium, the number of respondents was limited, ranging from 1 to 6 individuals (Figure 16). Total number of consumers in this survey was 386 respondents.

Consumers were surveyed about their practices of reusing or recycling water, energy (including heat), organic matter, and phosphorus obtained from sewage sludge and/or municipal wastewater. The results revealed that a majority of the participants opt to recycle or reuse water, energy, and organic matter, with 239, 208, and 260 respondents respectively. However, 122 consumers reported not recycling water, 133 not recycling energy, and 93 not recycling organic matter. There were also a small number of respondents (ranging from 33 to 45) who were unsure or had no opinion on the matter of reusing or recycling these resources. In contrast, the majority of respondents (173) admitted to not recycling phosphorus from sewage sludge and/or municipal wastewater, while only 134 participants reported doing so (Figure 17).

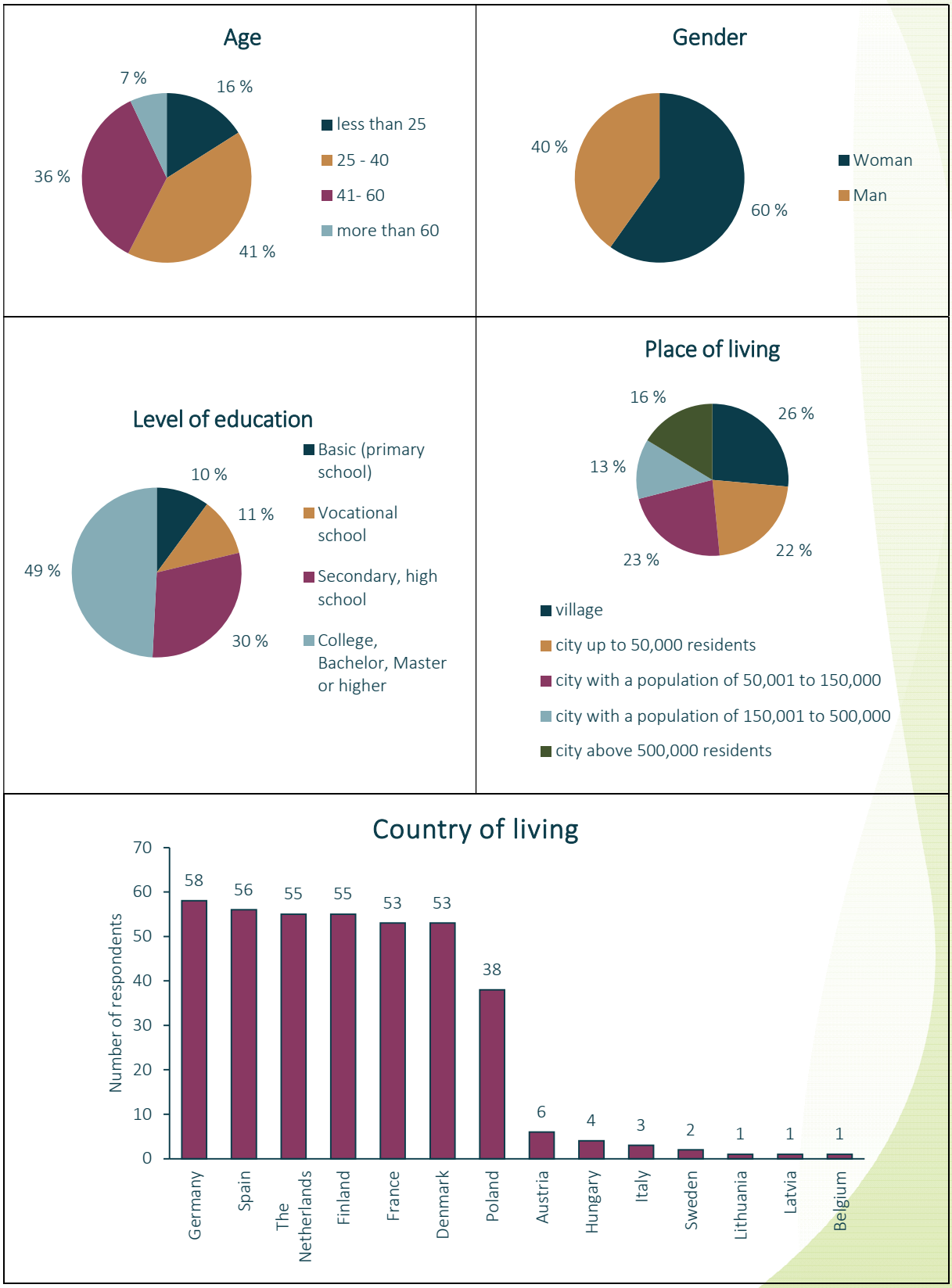


Figure 16. Basic characteristic of consumers.

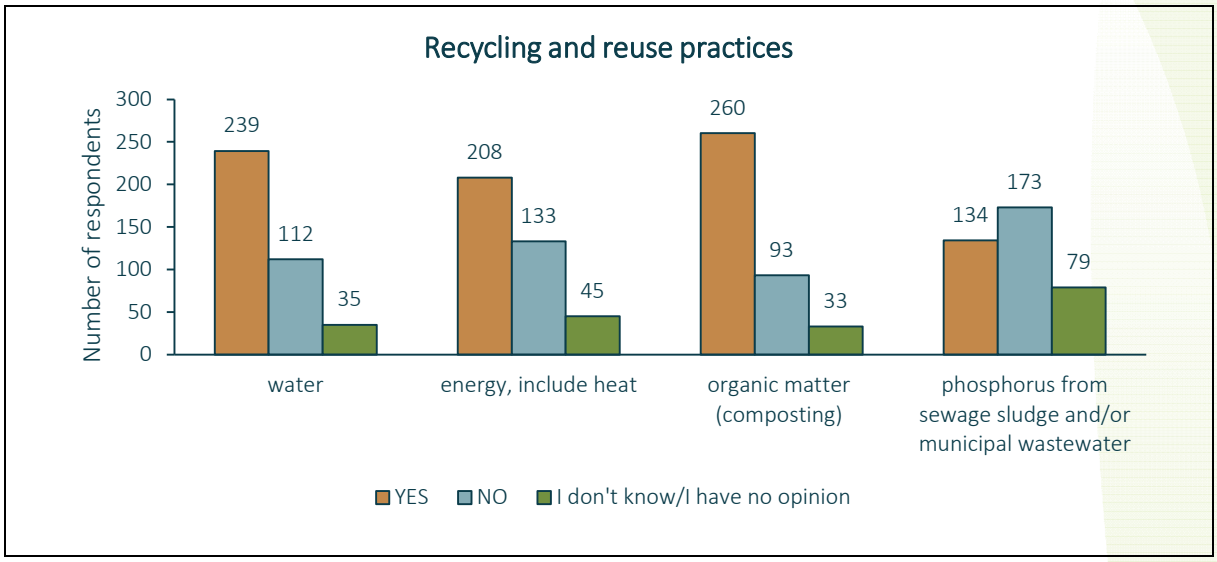


Figure 17. Consumer's recycling and reuse practices.

Consumers' responses regarding their opinion on the safety of the food products produced with the use of fertilisers are presented in Figure 18. The majority of surveyed consumers hold the belief that food products produced using plant residues are safe for consumption, with 261 respondents expressing agreement. Only 71 respondents disagree with this statement, and 54 respondents have no opinion on the matter. Additionally, approximately 205-220 respondents agree that organic raw materials such as algae, microorganisms, non-waste organic raw materials in their raw form or as a component in fertilisers, organic raw materials of animal origin (such as manure and slurry), and municipal biowaste can be safely utilised in food production. Conversely, 99-102 respondents either disagree or have no opinion regarding the safety of using these organic raw materials for food production. According to the survey, 188 respondents consider the utilisation of biodegradable industrial waste (such as digestates, sugar molasses, and biogas plant residues) to be safe. Similarly, 184 respondents believe that ashes resulting from the incineration of organic waste are safe. Additionally, 174 respondents perceive biochars as safe, while 173 respondents hold the same opinion about peat. In contrast, only 167 respondents consider fertilisers derived from mineral, fossil, or synthetic (artificial) resources to be safe. Furthermore, 161 respondents believe that municipal sewage is safe for utilisation. Municipal sewage sludge and struvite received the least amount of trust from respondents. Only 144 and 141 participants, respectively, agreed

that these fertilisers might be safe for use in food production. Among the analysed fertilisers, only four types (plant residues, organic raw materials that are not waste, organic raw materials of animal origin, and municipal biowaste) garnered agreement from over 50% of surveyed consumers regarding their safety for food production. However, for the majority of the examined fertilisers, a significant portion of respondents either had no opinion or disagreed with their safety for use.

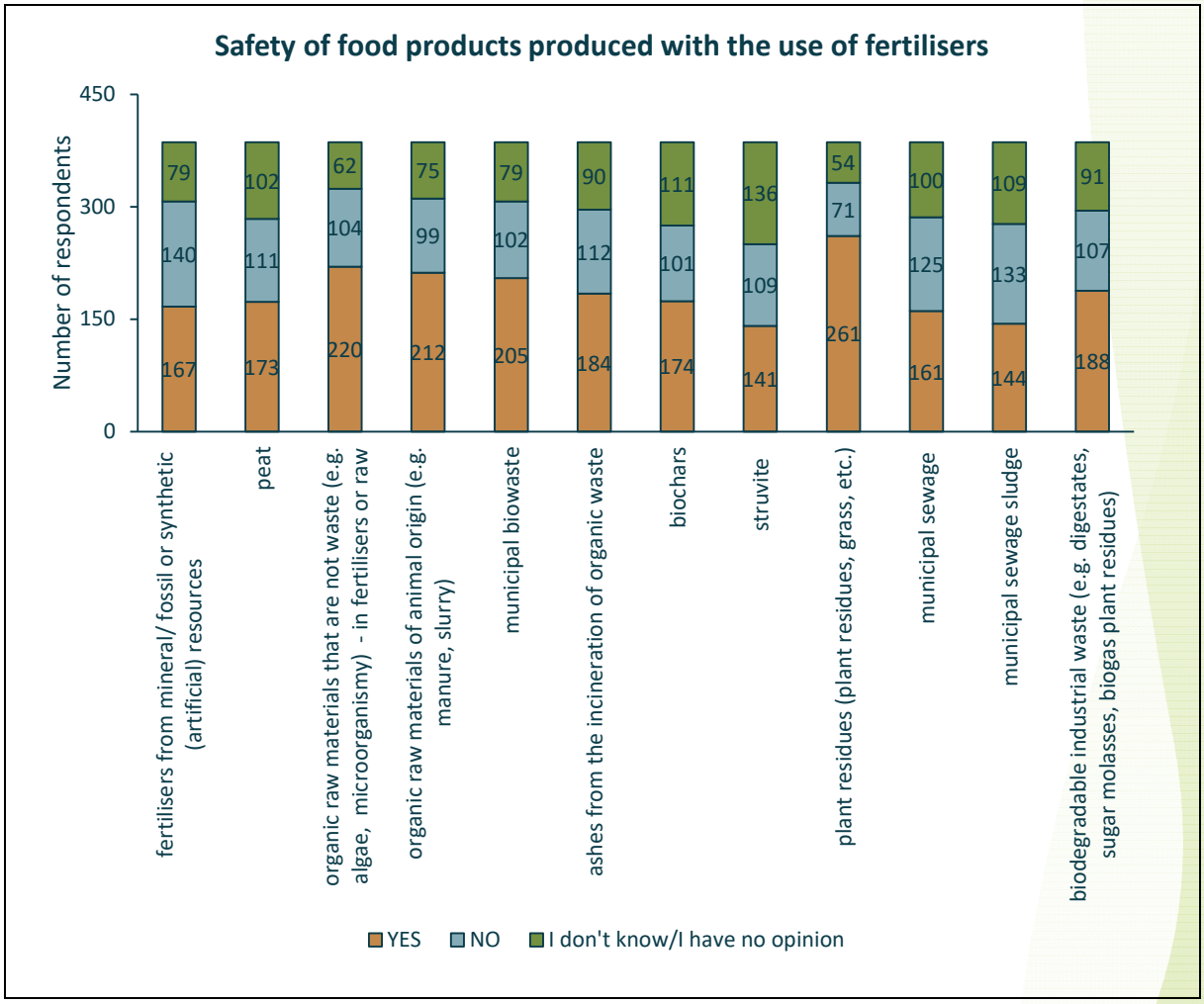


Figure 18. Safety of food products produced with the use of fertilisers according to the consumer.

Consumer attitudes towards the utilisation of waste-based fertilisers in food production are varied. The majority of consumers (124 responses) do not perceive any reason to treat them differently or consider them inferior. However, 109 respondents express a willingness to

consider their use only if convinced that these fertilisers meet stringent quality standards. On the other hand, 68 consumers do not pay much attention to the specifics of crop fertilisation; they prioritize the price and appearance of the final food products. Conversely, 58 respondents are opposed to the use of human excrement (municipal sewage) and waste-based fertilisers in agriculture, while 47 individuals are concerned about the potential environmental pollution associated with such fertilisation practices. Furthermore, 19 respondents cannot envision the use of waste-based fertilisers in food production (Figure 19).

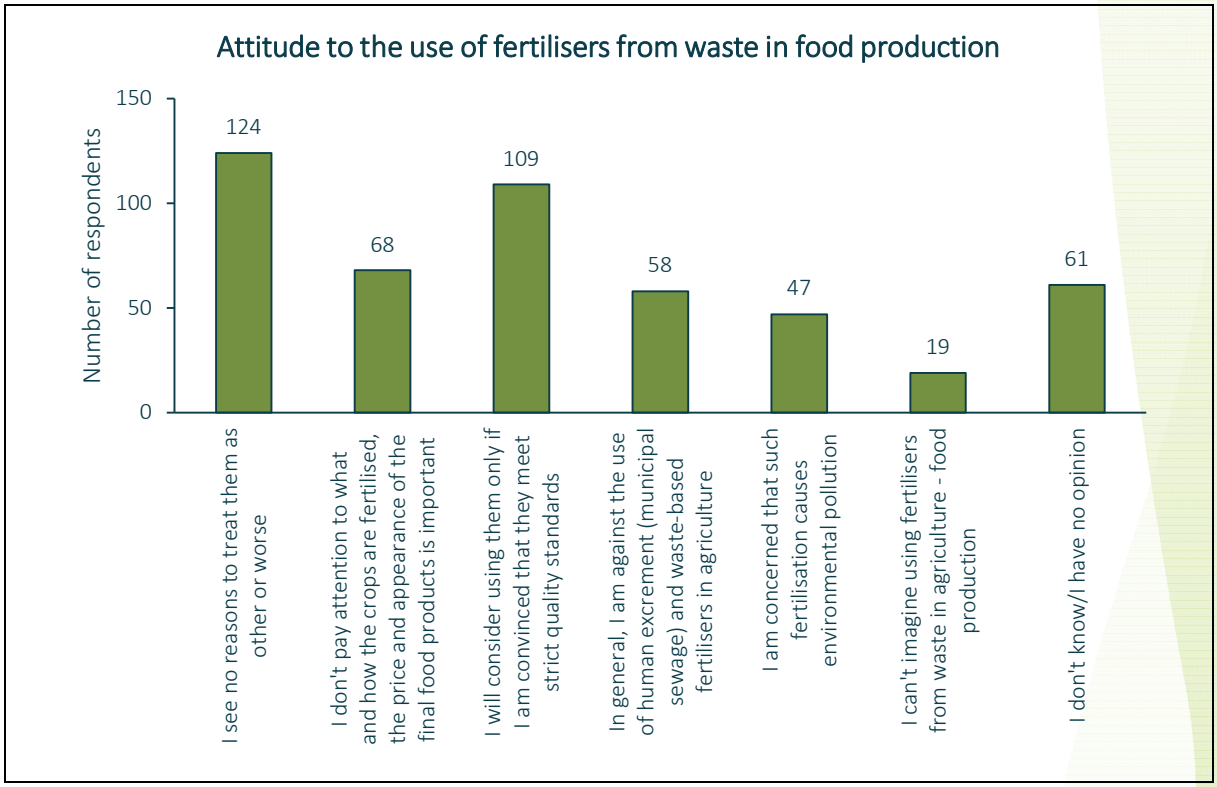


Figure 19. Attitude of consumers to the use of fertilisers from waste in food production.

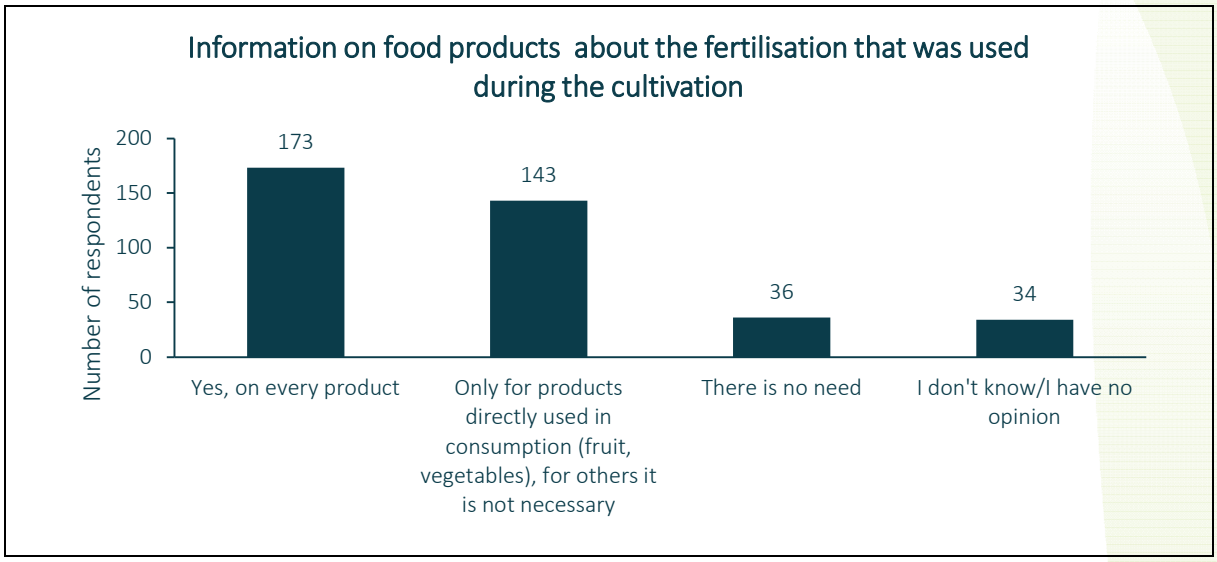


Figure 20. Information on food products about the fertilisation that was used during the cultivation.

The majority of respondents (173) believe that every food product should include information regarding the fertilisation methods employed during its cultivation. However, 143 respondents consider this information necessary only for products directly consumed, such as fruits and vegetables, while for other products, it is deemed unnecessary. On the other hand, 36 respondents see no need for providing such information, and 34 respondents have no opinion on the matter (Figure 20).

Likewise, 162 respondents emphasize the importance of clear information regarding the utilisation of waste-based fertilisers during production. However, 143 respondents believe that such information is only necessary if the products are directly consumed. In contrast, 50 respondents believe that there is no need to provide this type of information, while 31 respondents do not have a clear opinion on the matter (Figure 21).

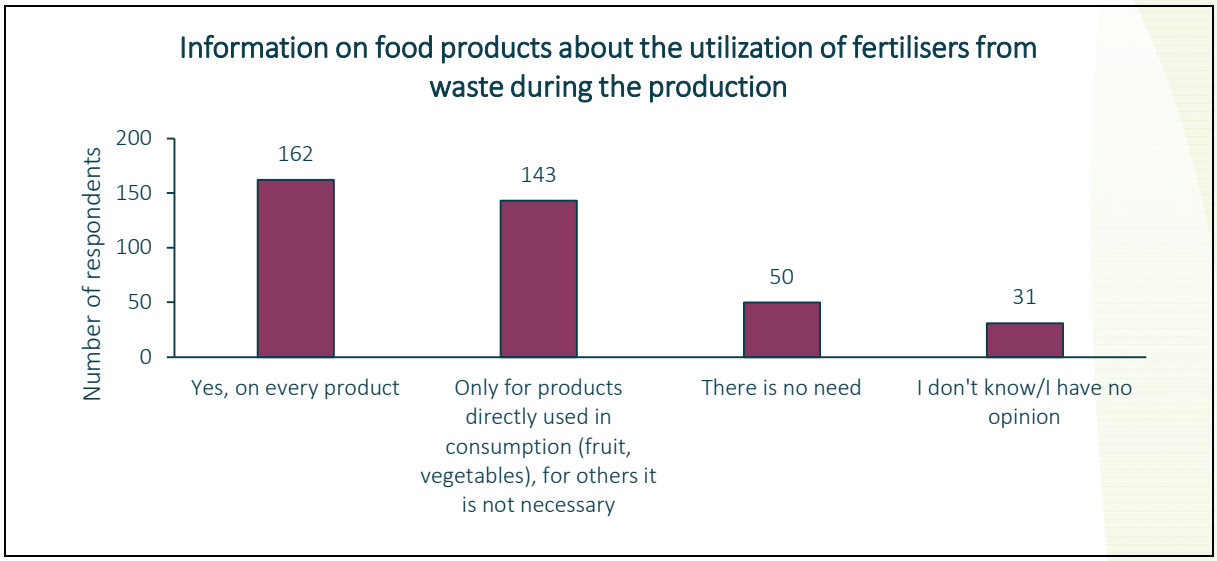


Figure 21. Information on food products about the utilisation of fertilisers from waste during the production.

Regarding food products produced using fertilisers derived from human excrement (municipal sewage), a higher number of respondents (187) expressed the necessity of providing information about their usage compared to food products produced with waste-based fertilisers (162). Conversely, fewer respondents (116) indicated that such information is only required for products directly consumed, such as fruits and vegetables. Furthermore, 49 respondents believed that there is no need to provide this type of information, while 34 respondents did not have a specific opinion on the matter (Figure 22).

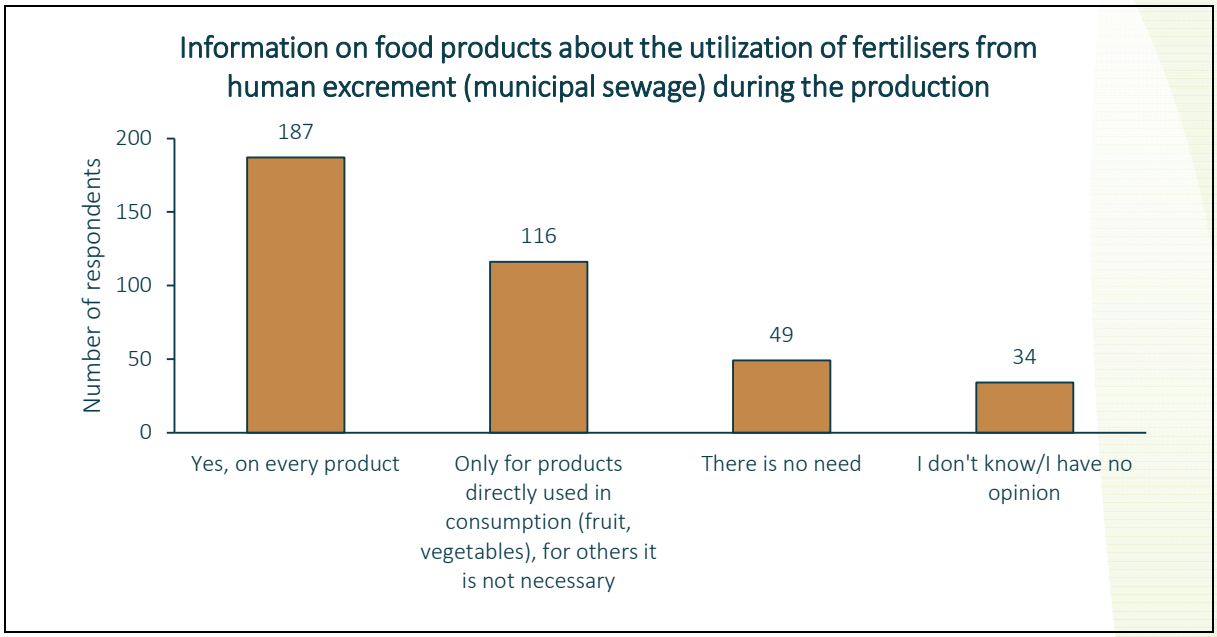


Figure 22. Information on food products about the utilisation of fertilisers from human excrement (municipal sewage) during the production.

The consumers were asked regarding their views on the approach of food and beverage producers towards utilising fertilisers made from waste. The majority of participants expressed the belief that these producers do not prioritize the content and method of crop fertilisation. Instead, they prioritize the price and appearance of the crops. Alternatively, some respondents stated that they would consider supporting the use of such fertilisers only if they were assured of their adherence to stringent quality standards. These perspectives were shared by 117 and 106 respondents, respectively. On the other hand, 82 respondents did not perceive any reason to treat food products grown with waste-based fertilisers as different or inferior. In contrast, 61 consumers opposed the utilisation of human waste (municipal sewage) as fertiliser, and 37 expressed concerns about potential environmental pollution resulting from such fertilisation. Furthermore, 67 respondents did not express a definitive opinion on the matter (Figure 23).

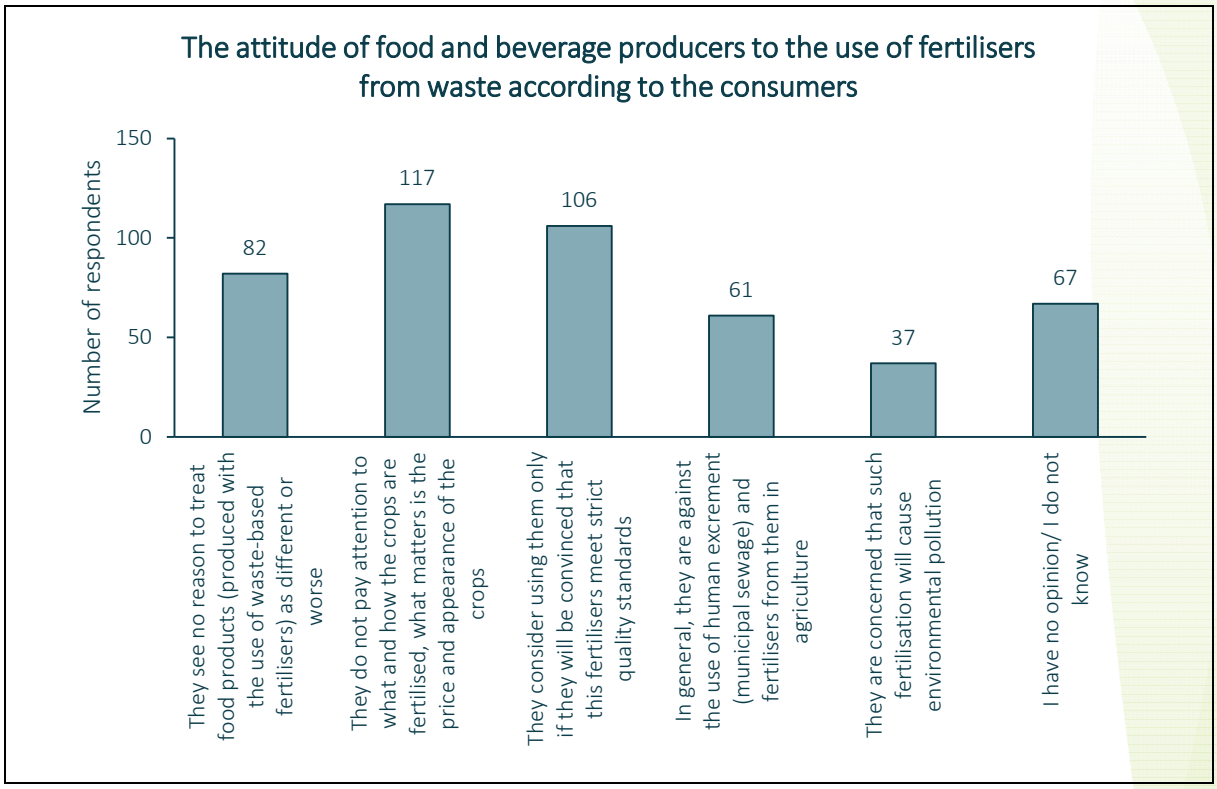


Figure 23. The attitude of food and beverage producers to the use of fertilisers from waste according to the consumers.

Consumers were surveyed regarding their stance on whether the price of food products, which are cultivated using waste-based fertilisers, should differ from those produced without such fertilisers, assuming the products have identical weight, appearance, and quality. The majority of respondents hold the belief that food products grown with waste-based fertilisers should be priced lower due to the likelihood of reduced production costs (120 respondents). Alternatively, some participants expressed the view that these products should be cheaper because consumers would not purchase them otherwise (52 respondents). Conversely, a portion of the respondents stated that these products should be priced higher due to the notion that environmentally-friendly practices entail greater expenses (37 respondents), or due to the probability of increased production costs (21 respondents). Furthermore, 85 respondents believe that the pricing should be the same for both types of products, while 49 respondents did not express a definitive opinion on the matter (Figure 24).

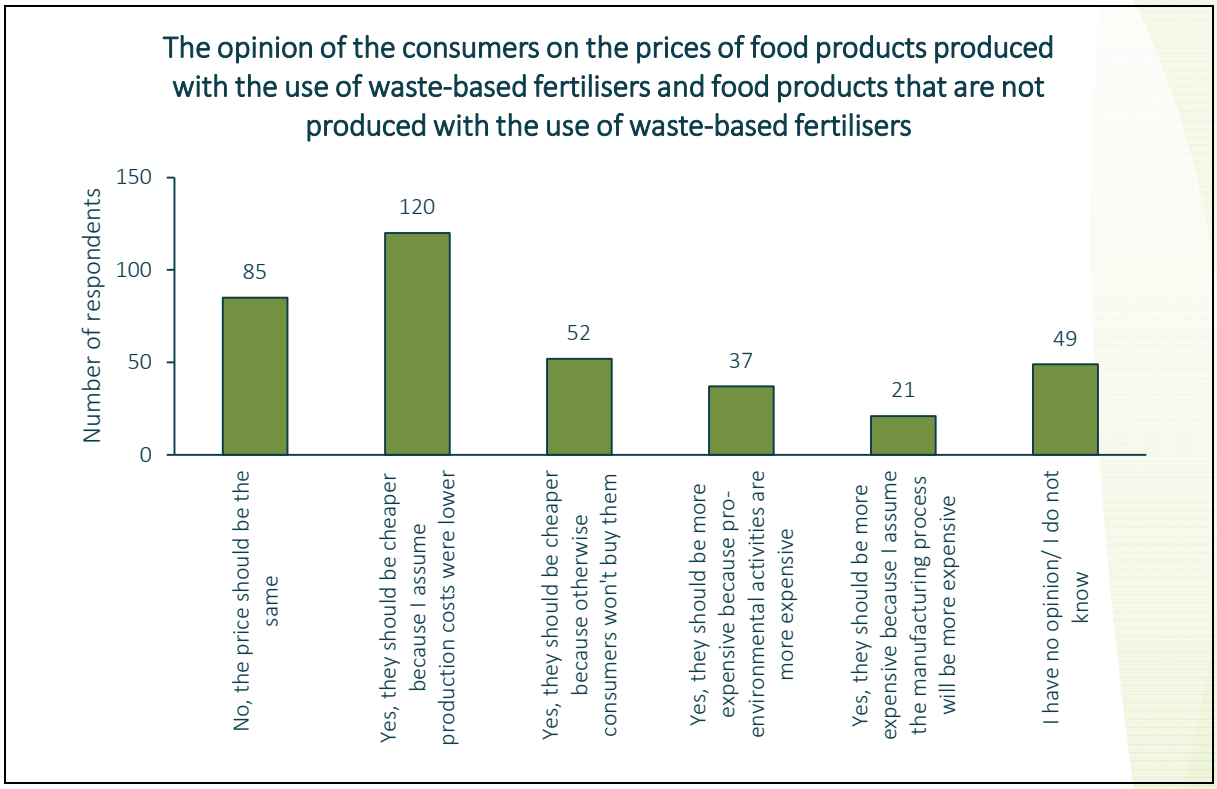


Figure 24. The opinion of the consumers on the prices of food products produced with the use of waste-based fertilisers and food products that are not produced with the use of waste-based fertilisers.

The majority of consumers (116 respondents) claim to possess a basic understanding of agriculture and food production, although not necessarily in a professional or scientific capacity. Additionally, 112 respondents expressed a strong interest in acquiring knowledge about agriculture and food production, albeit at a non-professional or non-scientific level. Out of the participants, 67 respondents acquired their knowledge and/or experience through employment in the agricultural or food production sector, either on a farm or in a related business. Another 51 respondents stated that they have no knowledge in this area, while 40 respondents either had no opinion or chose not to answer the question (Figure 25).

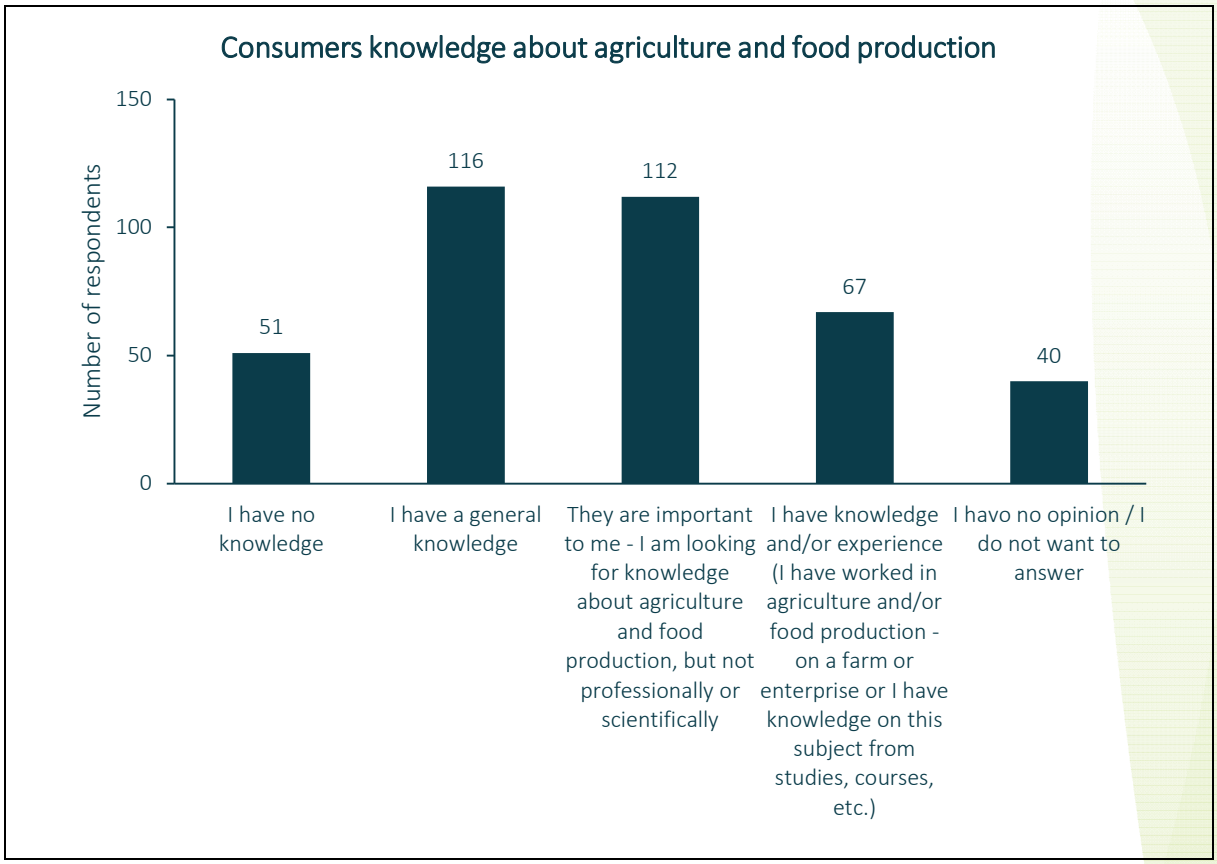


Figure 25. Consumers knowledge about agriculture and food production.

Fertiliser Producers (including Food and Beverage Producers)

Over 50% of the participants in the survey, which specifically focused on fertiliser producers including food and beverage producers, were between the ages of 41 and 60. Approximately 27% of the respondents were between the ages of 25 and 40, while around 20% were over 60 years old. None of the participants were below the age of 25. Furthermore, 70% identified themselves as men, 23% as women, and 7% chose not to disclose their gender (Figure 26).

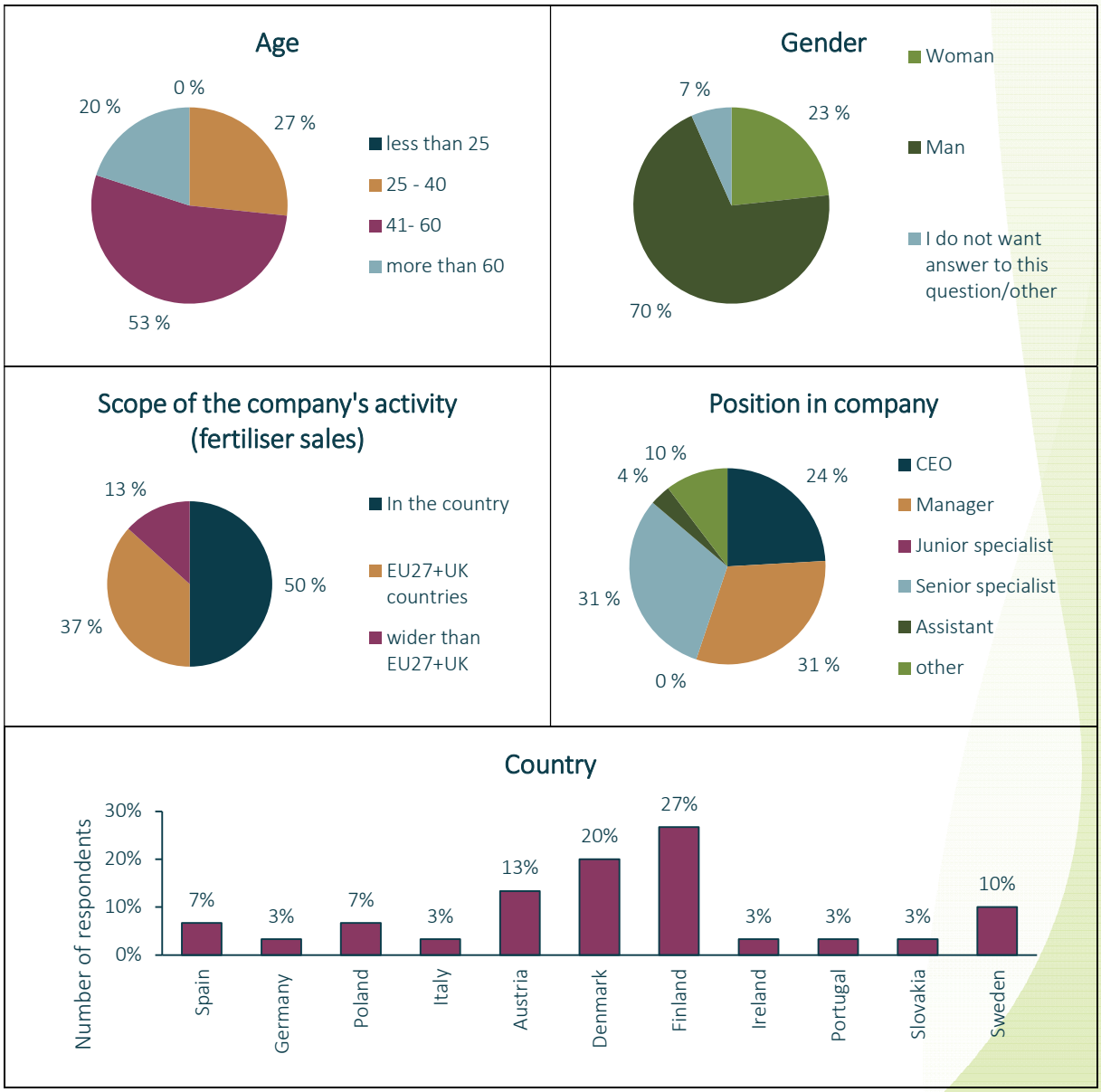


Figure 26. Basic characteristic of fertiliser producers (including food and beverage producers).

Regarding the respondents' roles within their respective company hierarchies, 24% occupied the position of Chief executive officer (CEO), while 31% were managers. Similarly, 31% identified themselves as senior specialists, and 4% reported being assistants. Additionally, 10% of the participants described their work positions as something other than the mentioned categories. It is worth noting that there were no junior specialists among the respondents. The majority of the respondents work for companies primarily focused on fertiliser sales within their country of residence (50%). Around 37% of the participants sell fertilisers in both the UK and EU27 countries, while 13% have a broader sales scope that extends beyond the UK and EU27 countries. The respondents in the survey hail from various European countries. Approximately 27% of the participants are from Finland, while 20% come from Denmark. Austria is represented by 13% of the respondents, and Sweden by 10%. Spain and Poland each account for 7% of the participants. Additionally, Germany, Italy, Ireland, Portugal, and Slovakia are each represented by 3% of the respondents. The total number of respondents was 30 (Figure 26).

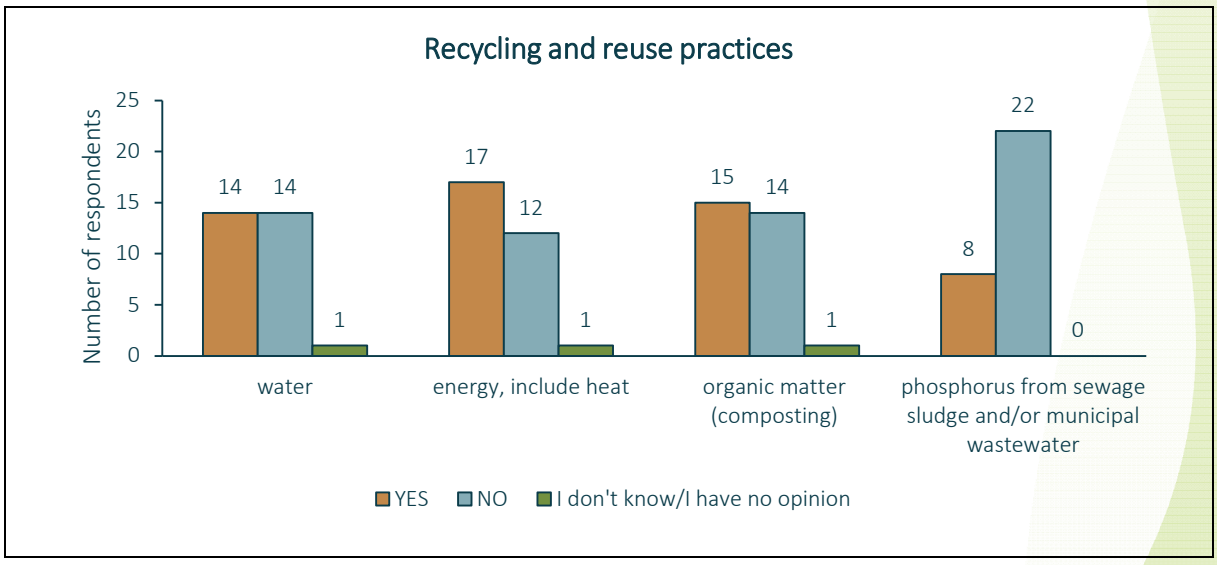


Figure 27. Recycling and reuse practices in producers' companies.

The survey targeted producers and inquired about their practices concerning the reuse or recycling of water, energy (including heat), organic matter, and phosphorus derived from sewage sludge and/or municipal wastewater. The results indicated that an equal number of

companies engage in water recycling and those that do not, with 14 respondents each. One respondent either had no opinion or lacked knowledge on the matter. Similarly, organic matter is composted by 15 companies, while 14 companies do not recycle organic matter. The majority of respondents' companies (17) recycle and reuse energy and heat, whereas 12 companies do not. In contrast, most respondents (22) admitted to not recycling phosphorus from sewage sludge and/or municipal wastewater, while only 8 participants reported doing so (Figure 27).

The representatives of producers were surveyed about the materials used or considered to produce fertilisers in their companies. According to all the respondents, the majority of companies (19) utilise or consider using organic raw materials of animal origin, such as manure and slurry, for fertiliser production. However, 9 respondents stated that their companies do not consider this option. Similarly, 17 respondents expressed their willingness to use biodegradable industrial waste, such as digestates, sugar molasses, and biogas plant residues, while 16 respondents reported using or considering the use of non-waste organic raw materials (e.g., algae, microorganisms) and plant residues (e.g., grass) (Figure 28).

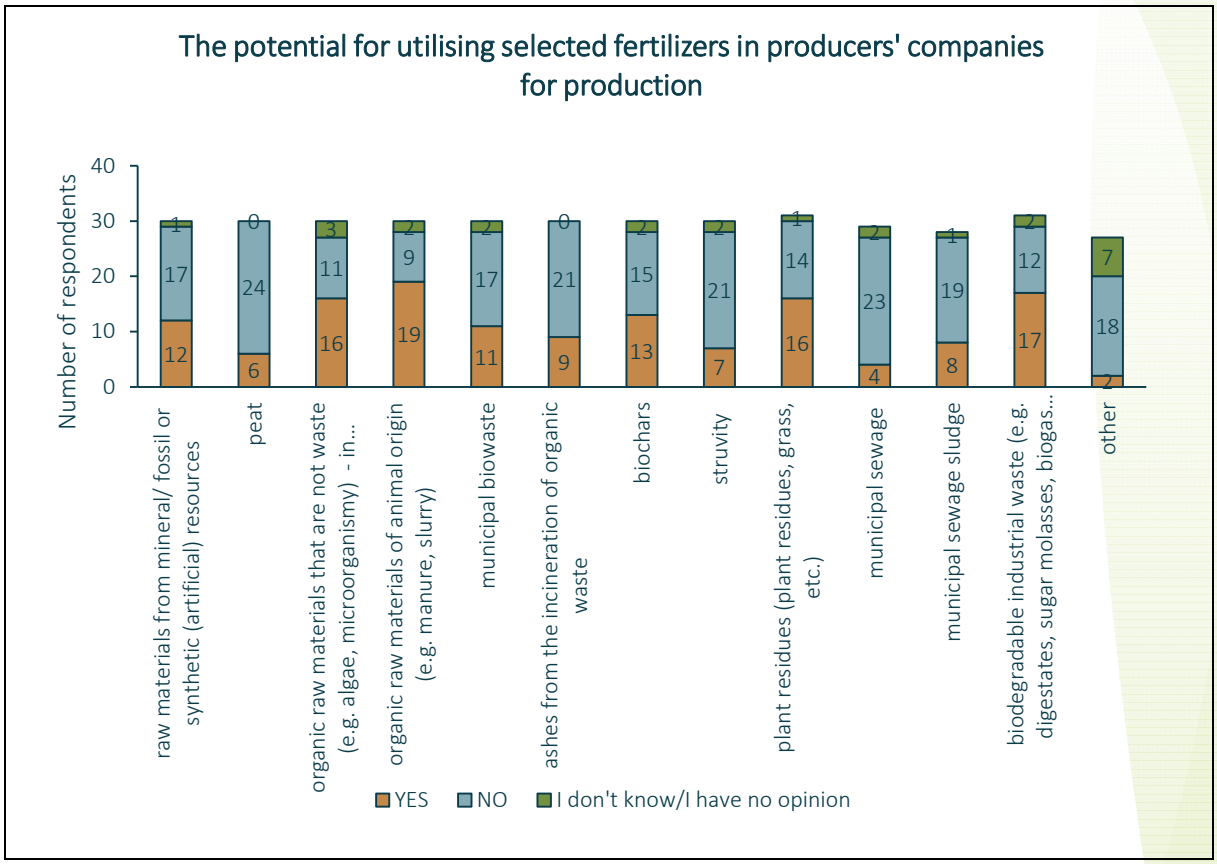


Figure 28. The potential for utilisers in producers' companies for production.

Additionally, 12 companies mentioned the use or potential use of raw materials from mineral/fossil or synthetic sources, 11 companies mentioned municipal biowaste, and 9 companies mentioned ashes from the incineration of organic waste. However, respectively, 17, 17, and 21 companies did not declare the possibility of using these materials. In terms of specific materials, 8 companies use or consider using municipal sewage sludge, 7 companies use or consider using struvite, 6 companies use or consider using peat, and 4 companies use or consider using municipal sewage for fertiliser production. On the other hand, 19, 21, 24, and 23 companies, respectively, do not use or consider using these materials for production. There were also 2 companies that mentioned the use of other materials, while 18 companies responded with "no" and 7 companies did not provide an opinion on the matter. A portion of the respondents either expressed no opinion or stated a lack of knowledge regarding whether

their companies utilise or consider using all the mentioned materials for fertiliser production (Figure 28).

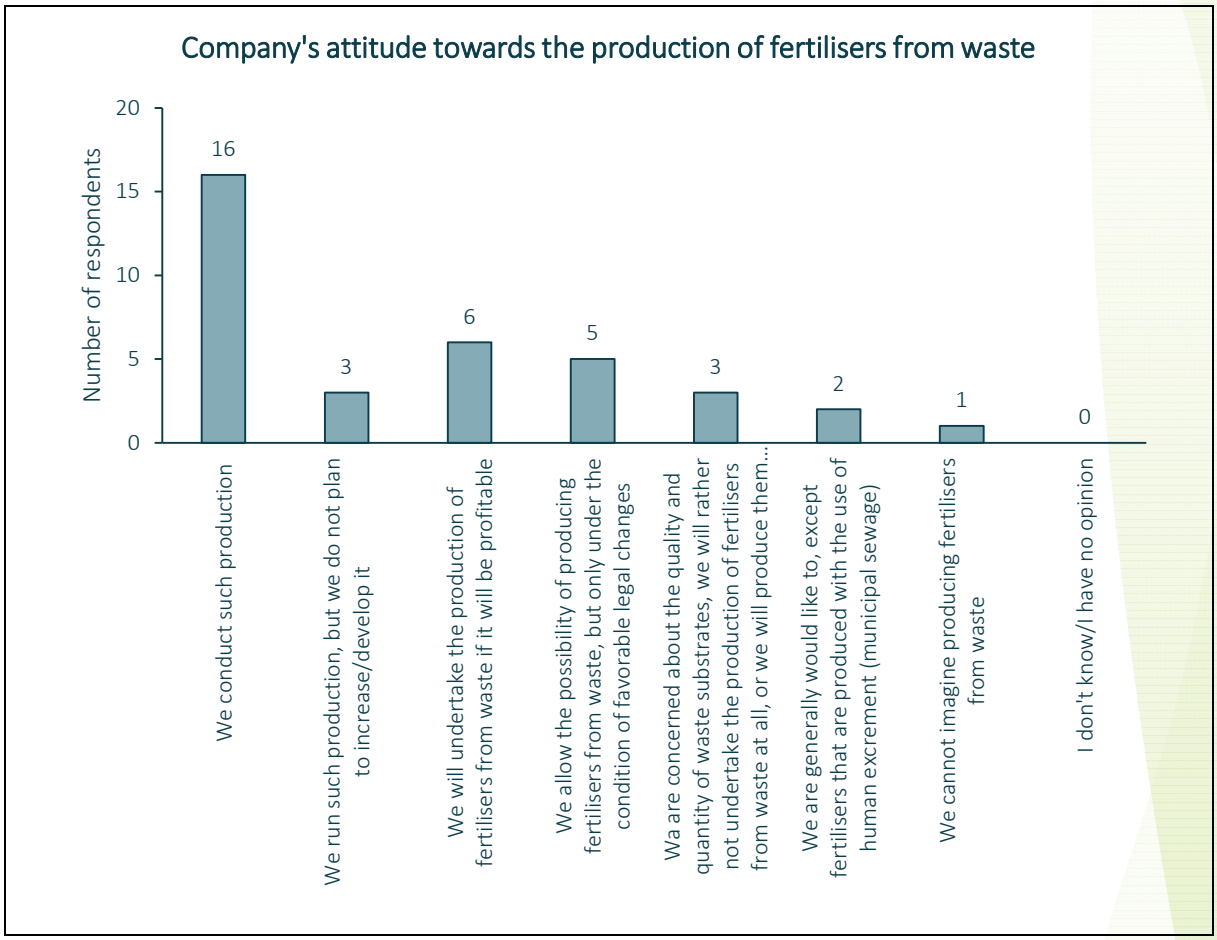


Figure 29. Company's attitude towards the production of fertilisers from waste.

Many of the surveyed representatives from fertiliser producers (16) indicated that their companies engage in the production of fertilisers from waste materials. 6 respondents expressed that their companies would undertake such production if it proves to be profitable, while 5 respondents expressed a willingness to produce fertilisers from waste, but only if there are favourable legal changes in place. 3 companies are currently involved in this production but do not plan to expand or develop it further. Similarly, 3 companies expressed concerns regarding the quality and quantity of waste substrates, leading them to prefer not to engage in fertiliser production from waste. 2 companies are open to the idea of producing fertilisers from waste, except those produced using human excrement (municipal sewage), while 1

company cannot envision engaging in fertiliser production from waste materials at all (Figure 29).

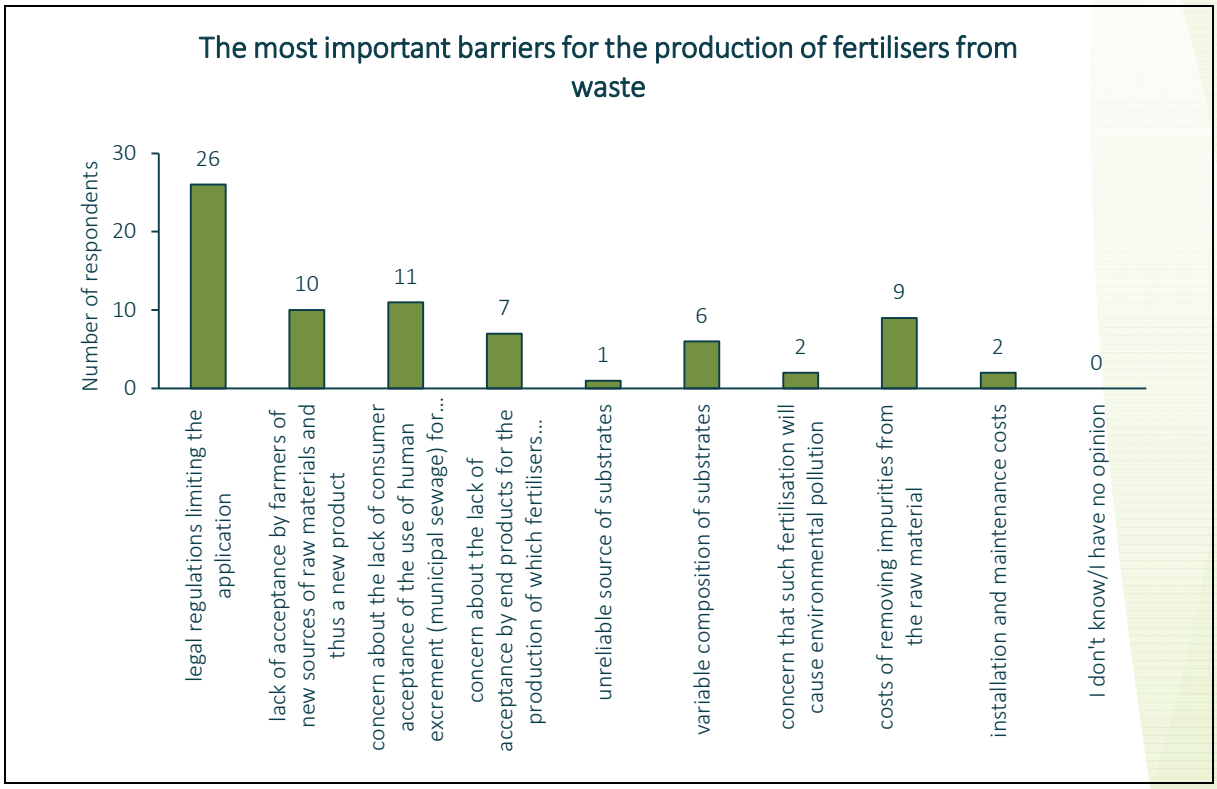


Figure 30. The most important barriers for the production of fertilisers from waste in producers' companies.

Survey participants were asked about the main obstacles to producing fertilisers from waste. The majority of respondents (26) identified legal regulations as the most significant barrier. Additionally, 11 participants expressed concerns about the public's reluctance to accept the use of human waste (municipal sewage) for food production. Another 10 respondents highlighted farmers' resistance to adopting new sources of raw materials and the resulting challenges in creating a new product. The cost of purifying raw materials was identified as the most important barrier by 9 respondents. Furthermore, 7 respondents were worried about the lack of acceptance for end products derived from waste fertilisers, while 6 respondents emphasised the variable composition of substrates as a concern. For 2 participants, the costs associated with installing and maintaining the necessary infrastructure, as well as the fear of environmental pollution caused by such fertilisation, were considered important barriers.

Finally, only 1 respondent mentioned that an unreliable supply of substrates could pose a significant obstacle (Figure 30).

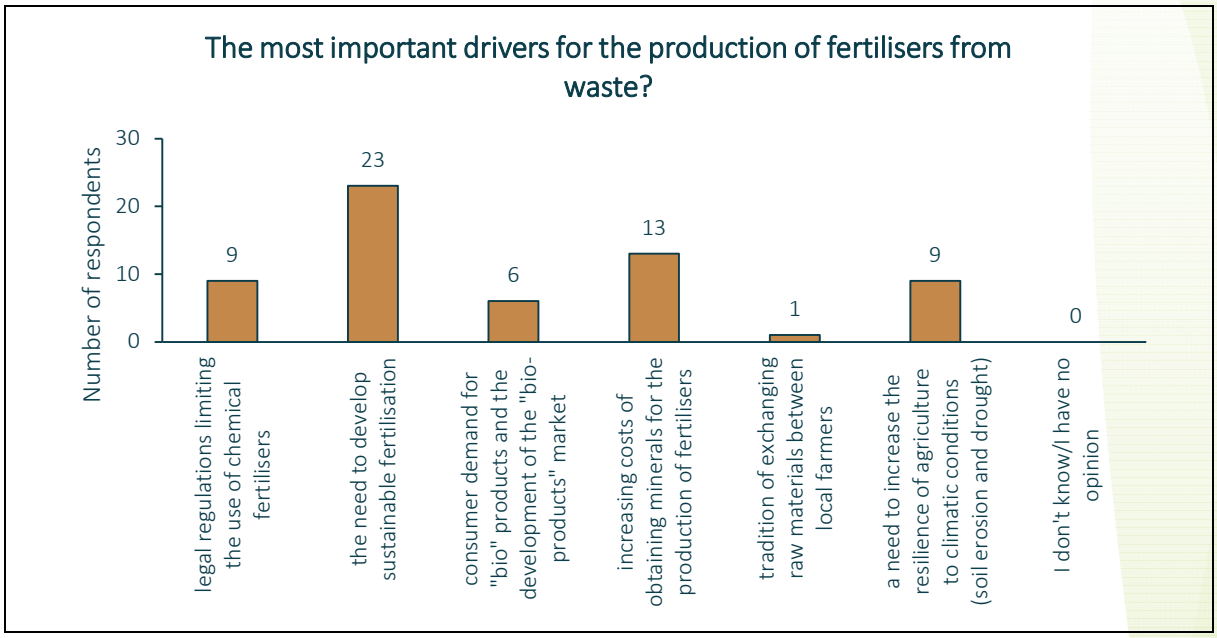


Figure 31. The most important drivers for the production of fertilisers from waste in producers' companies.

23 respondents identified the promotion of sustainable fertilisation as a key factor driving the production of fertilisers from waste. Additionally, 13 producers believed that higher costs associated with obtaining minerals for fertiliser production would have a positive impact on the fertiliser market. 9 respondents emphasised the influence of legal regulations that limit the use of chemical fertilisers, as well as the need to enhance agriculture's resilience to climate-related challenges such as soil erosion and drought. Among the participants, 6 individuals highlighted consumer demand for "bio" products and the growth of the "bio-products" market as significant drivers. Finally, only 1 respondent pointed out the tradition of exchanging raw materials among local farmers as a driving factor (Figure 31).

The producers were requested to share their perspective on the farmers' attitude towards utilising fertilisers made from waste. Out of the total respondents, 20 individuals expressed that farmers would opt for waste-derived fertilisers only if they are priced lower than fertilisers made from traditional raw materials. 15 respondents believed that farmers would consider using these fertilisers if they were convinced that they meet strict quality standards.

Additionally, 11 respondents stated that farmers would value and consider waste-derived fertilisers if they were aware of their advantages and disadvantages. However, 1 respondent expressed the opinion that farmers, in general, oppose the utilisation of human excrement (municipal sewage) and the fertilisers derived from them, while another respondent had no opinion on this matter (Figure 32).

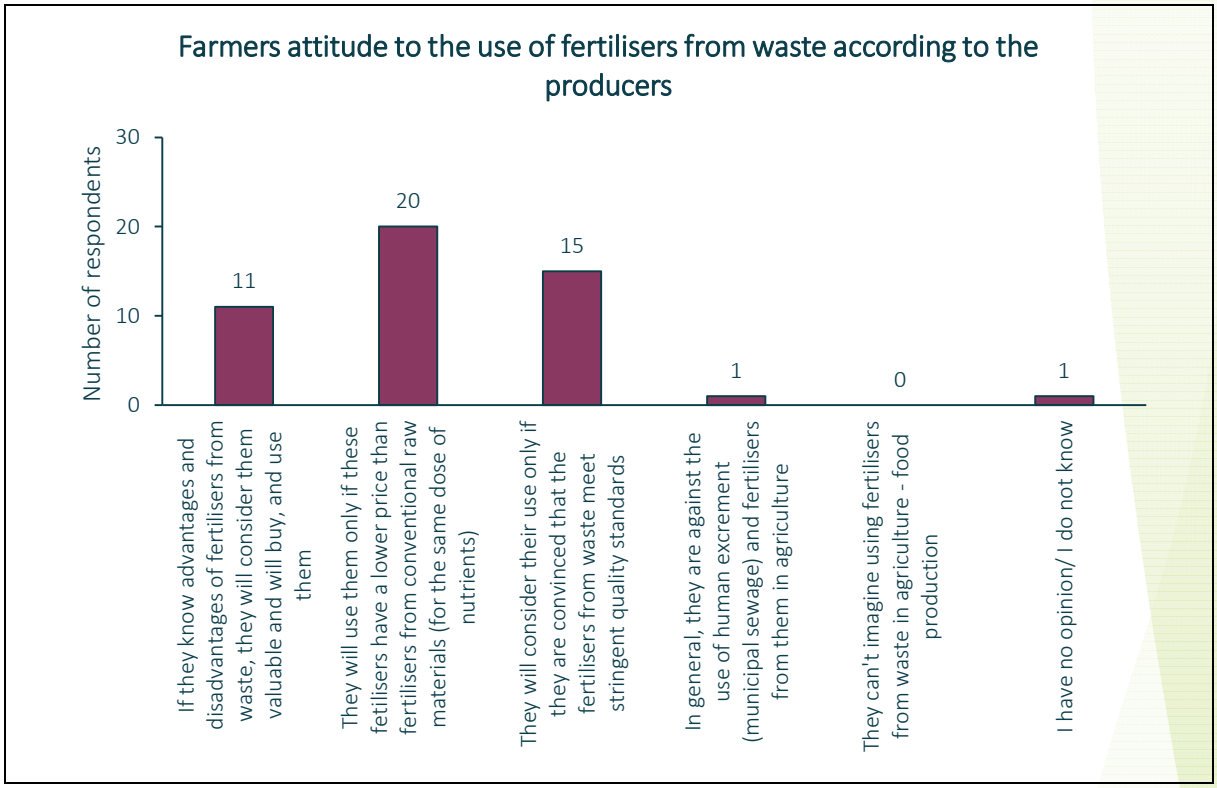


Figure 32. Farmers attitude to the use of fertilisers from waste according to the producers.

The producers were queried about their opinion on whether the price of fertilisers derived from waste should vary compared to fertilisers manufactured from conventional materials, assuming that both types of fertilisers have an equal package weight and nutrient content. Among the respondents, 11 individuals asserted that the price for both types of fertilisers should be identical. Similarly, 11 respondents expressed the view that waste-based fertilisers ought to be cheaper, while 6 respondents indicated that fertilisers produced from waste materials should be priced higher. Additionally, 2 respondents did not provide any opinion on this matter (Figure 33).

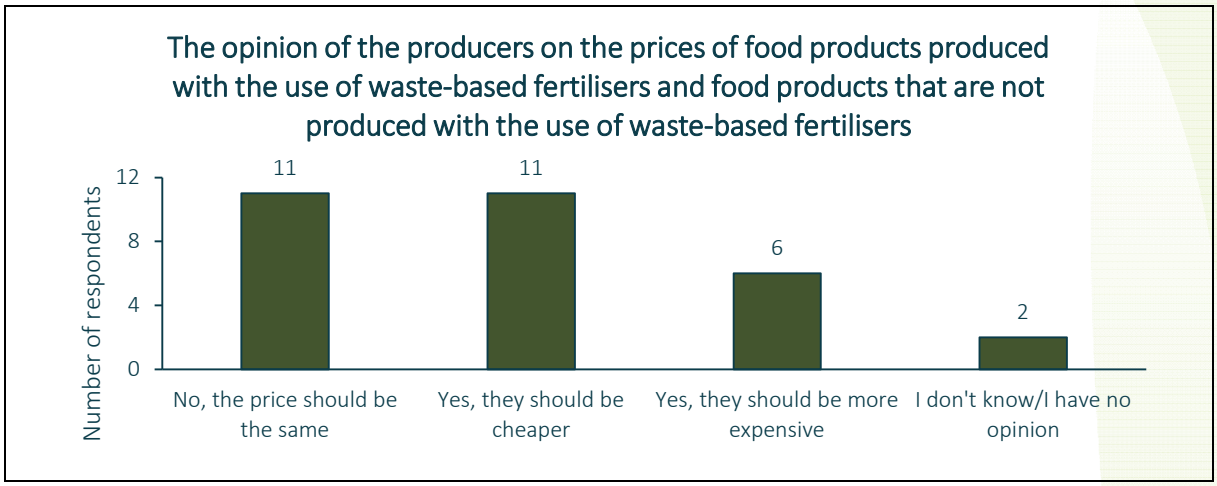


Figure 33. The opinion of the producers on the prices of food products produced with the use of waste-based fertilisers and food products that are not produced with the use of waste-based fertilisers.

The respondents who previously expressed the opinion that waste-based fertilisers should be priced lower than fertilisers made from conventional materials were subsequently asked about the primary reasons behind their statement. According to the majority of respondents, the main reason for this belief is that if waste-based fertilisers are not priced lower, farmers would opt for the already familiar fertilisers (as mentioned by 6 respondents). Additionally, 3 respondents emphasis

ed that farmers might be concerned about the potentially lower efficiency and effectiveness of waste-based fertilisers (resulting in a higher dose per hectare of arable land), and therefore, the price should be lower to remain competitive. Furthermore, 2 respondents presumed that the raw materials used in the production of waste-based fertilisers would be less expensive, which in turn should lead to a lower price (Figure 34).

In a similar vein, respondents who previously expressed the opinion that waste-based fertilisers should be priced higher than fertilisers made from conventional materials were then asked about the primary reasons behind their stance. According to 5 respondents, the main reason for this belief is their assumption that waste-based fertilisers will be more costly. Furthermore, 3 respondents highlighted the added value of waste-based fertilisers in terms of respecting natural resources during their production. Notably, none of the respondents mentioned the following reasons: the potential for waste-based fertilisers to exhibit higher

efficiency and effectiveness (resulting in a lower dose per hectare of arable land) and therefore justifying a higher price, or the positive impact they might have on soil organic matter (Figure 35).

Figure 34. The main reason why fertilisers from waste should have a lower price according to the producers.

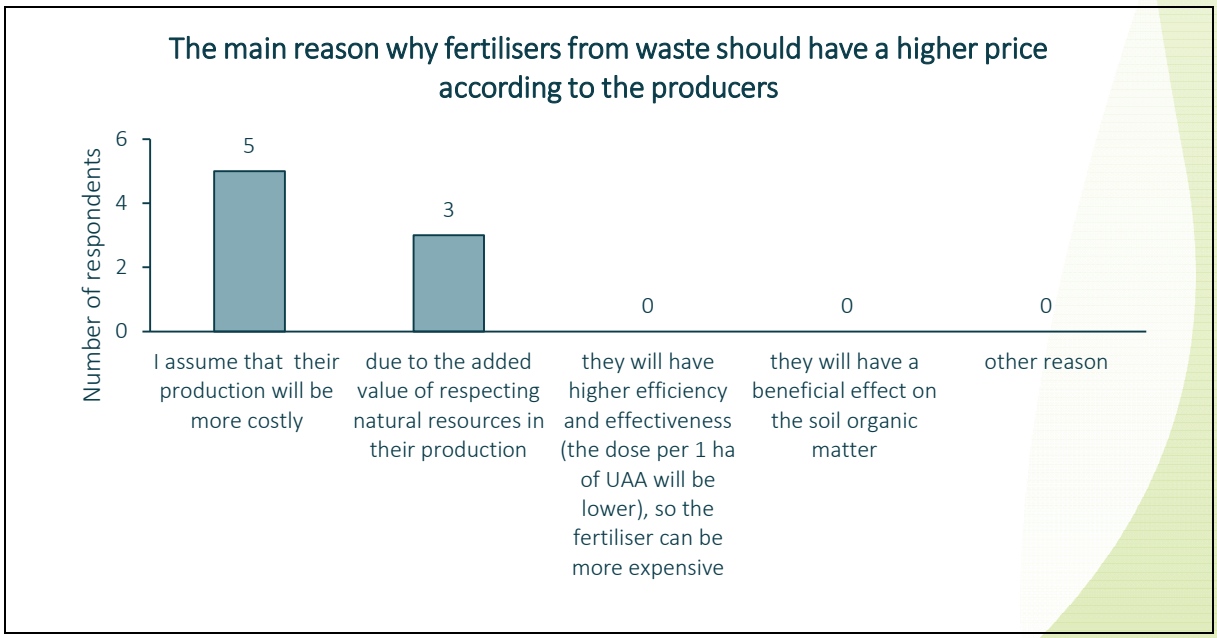


Figure 35. The main reason why fertilisers from waste should have a higher price according to the producers.

The majority of producers (20 respondents) hold the belief that comprehensive information regarding the source of raw materials used in fertiliser production should be displayed on the packaging of all fertiliser types. Conversely, 6 respondents believe that such information is unnecessary. Additionally, 2 respondents expressed the view that this kind of information should always be included on fertilisers intended for use in vegetables and fruits, as these products are directly consumed. However, for other types of fertilisers, they deemed it unnecessary. Furthermore, 2 other respondents emphasised the necessity of providing information on the origin of fertilisers specifically for waste-based fertilisers derived from municipal sewage (Figure 36).

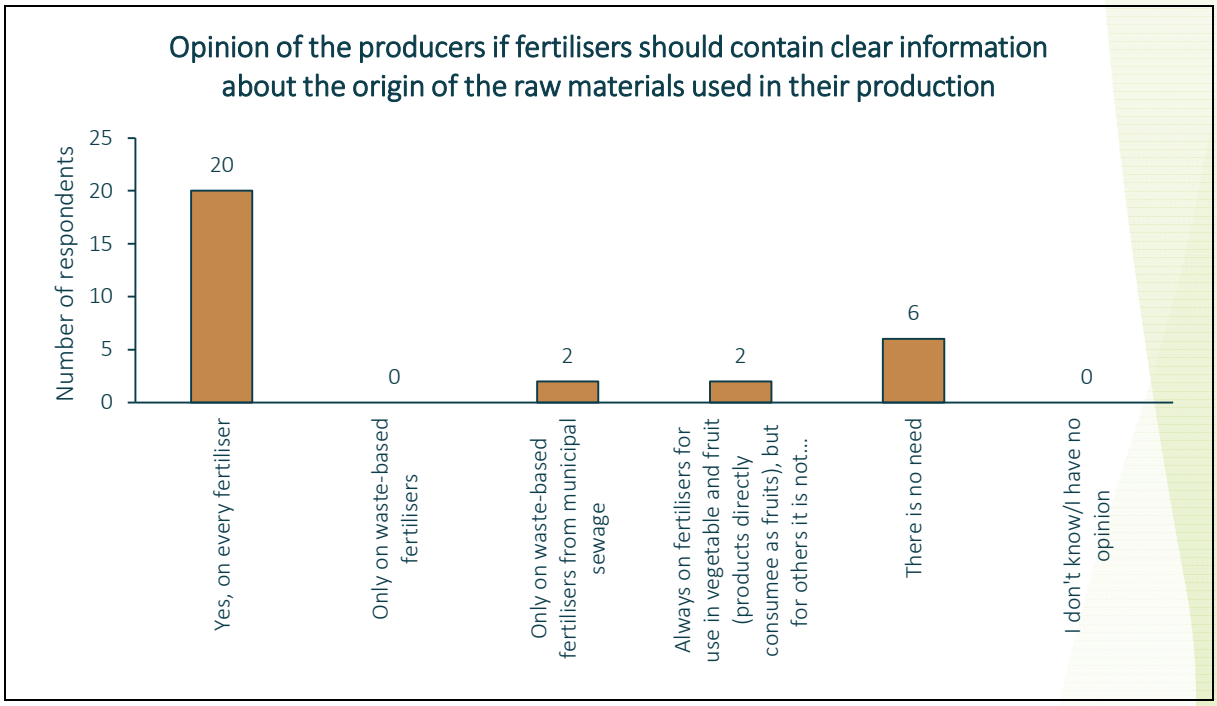


Figure 36. Opinion of the producers if fertilisers should contain clear information about the origin of the raw materials used in their production.

Farmers

The majority of the farmers surveyed fell within the age range of 25 to 40, comprising 43% of the respondents, followed by those aged between 41 and 60, accounting for 39% of the respondents. Farmers under the age of 25 constituted 13% of the participants, while only 5% were older than 60. In terms of gender distribution, 53% of the respondents were male, 45% were female, and 2% chose not to disclose their gender. Roughly 43% of the participants had completed secondary education, whereas 25% held higher education degrees. Additionally, 19% of the respondents had graduated from a vocational school, and 13% had completed primary school. Furthermore, more than 90% identified themselves as farmers who either owned or co-owned a farm. Approximately 4.7% were employed on a full-time basis, while 2.2% held part-time employment. The remaining respondents consisted of students (1.2%), business owners (0.7%), retirees (0.4%), unemployed individuals (0.4%), or fell into other categories (0.1%) (Figure 37).

The distribution of agricultural lands is relatively balanced. Around 19% of the respondents reported having farms ranging from 5 to 9.99 hectares, while 18% had farms between 2 and 4.99 hectares. An additional 18% had farms smaller than 2 hectares. Approximately 17% of the farms fell within the range of 10 to 19.99 hectares, and 12% of the farms were sized between 20 and 49.99 hectares. Farms measuring 50 to 99.99 hectares accounted for 8% of all farms, as did those larger than 100 hectares. The survey primarily included participants from six particular countries: Hungary, France, Germany, Spain, Romania, and Italy, with respondent counts of 125, 111, 110, 106, 104, and 102, respectively. In Poland, 12 individuals responded to the questionnaire, while Austria had 11 respondents. Ireland, Finland, and Denmark were each represented by 2 respondents, and Croatia had only 1 respondent. A total of 688 farmers were surveyed (Figure 37).

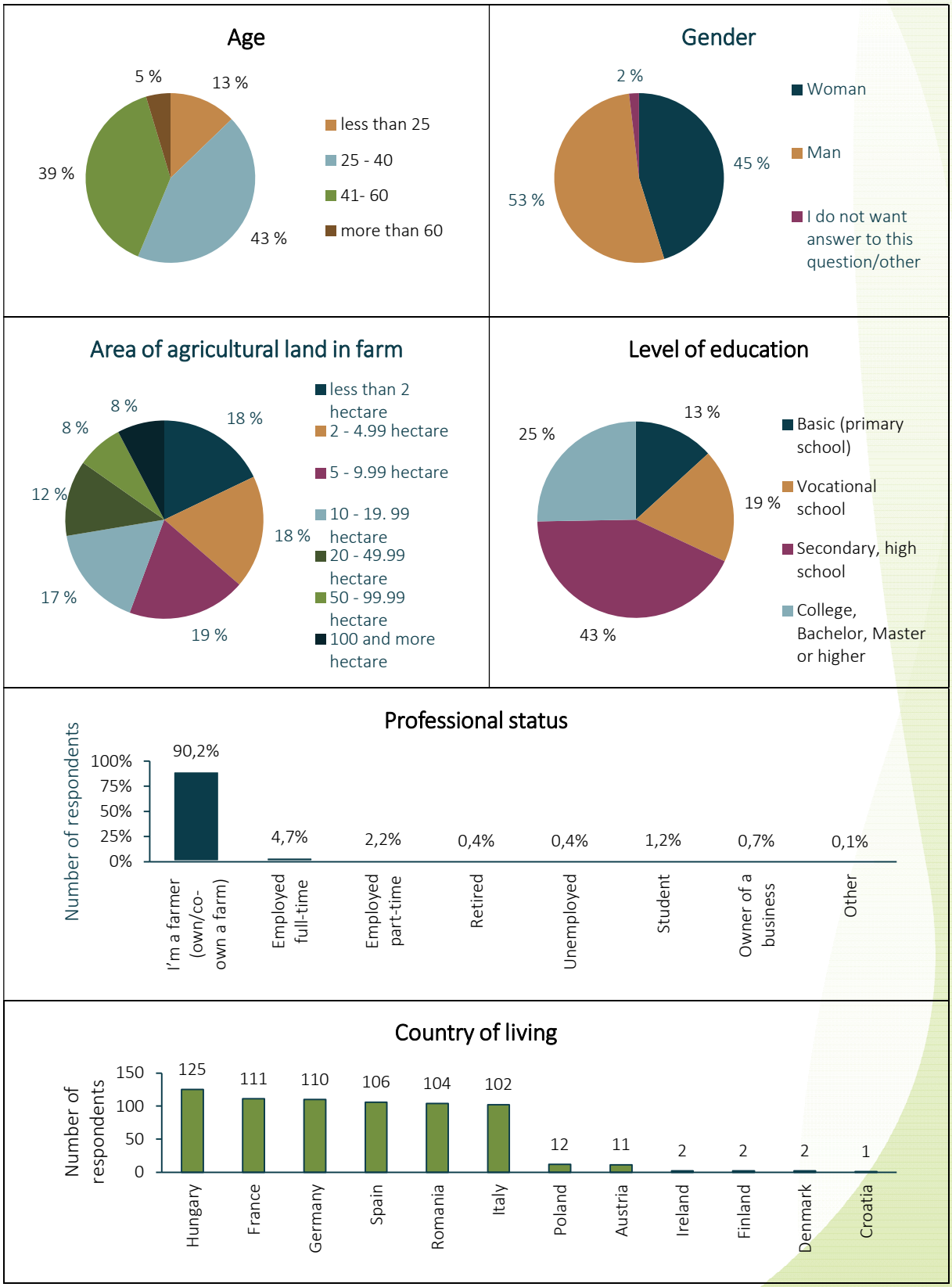


Figure 37. Basic characteristic of farmers.

The farmers were queried about their adoption of pro-environmental practices in agriculture. Out of the respondents, 175 confirmed using subsidies for agri-environment or agri-environment-climate measures, while 132 reported utilising subsidies specifically for organic farming. Additionally, 59 participants mentioned employing other subsidies aimed at reducing environmental pollution. On the contrary, 159 respondents declared that they do not utilise any agricultural subsidies, including direct subsidies. Furthermore, 133 respondents solely applied for direct subsidies. It's worth noting that 32 respondents chose not to provide an answer to this particular question (Figure 38).

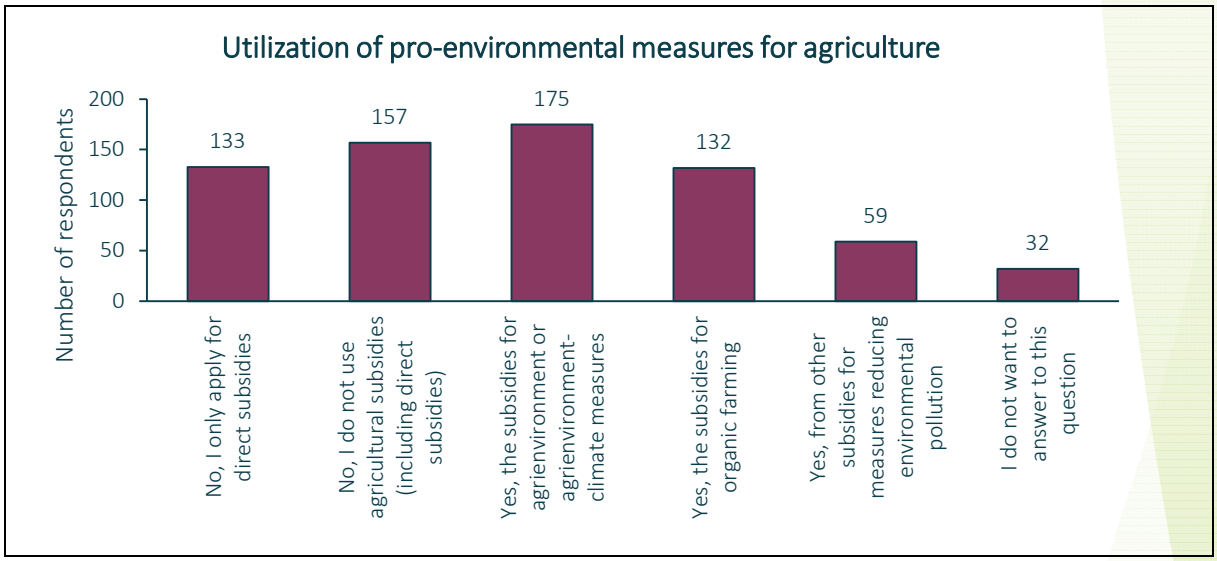


Figure 38. Utilisation of pro-environmental measures for agriculture.

Furthermore, 239 farmers rely on agricultural advisory services for assistance in completing subsidy applications, as well as for substantive matters and/or training purposes. Additionally, 179 respondents specifically seek support from agricultural advisory services when completing subsidy applications, while 120 respondents rely on them for substantive matters and/or training. On the other hand, 131 respondents do not utilise the support of agricultural advisory services at all, and 19 respondents chose not to provide an answer to this question (Figure 39).

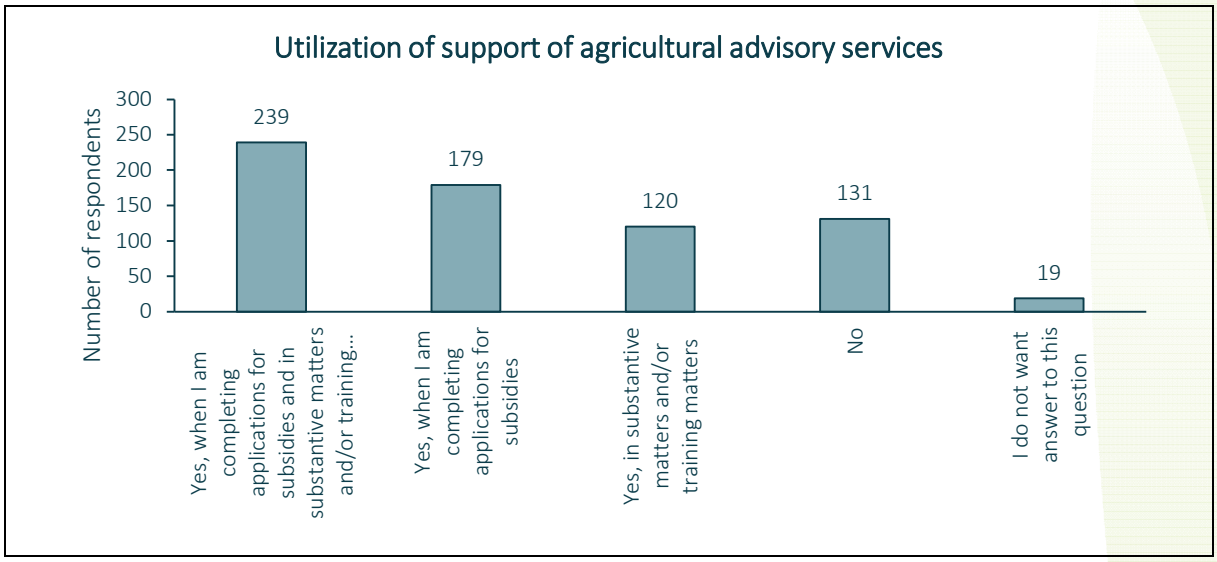


Figure 39. Utilisation of support of agricultural advisory services.

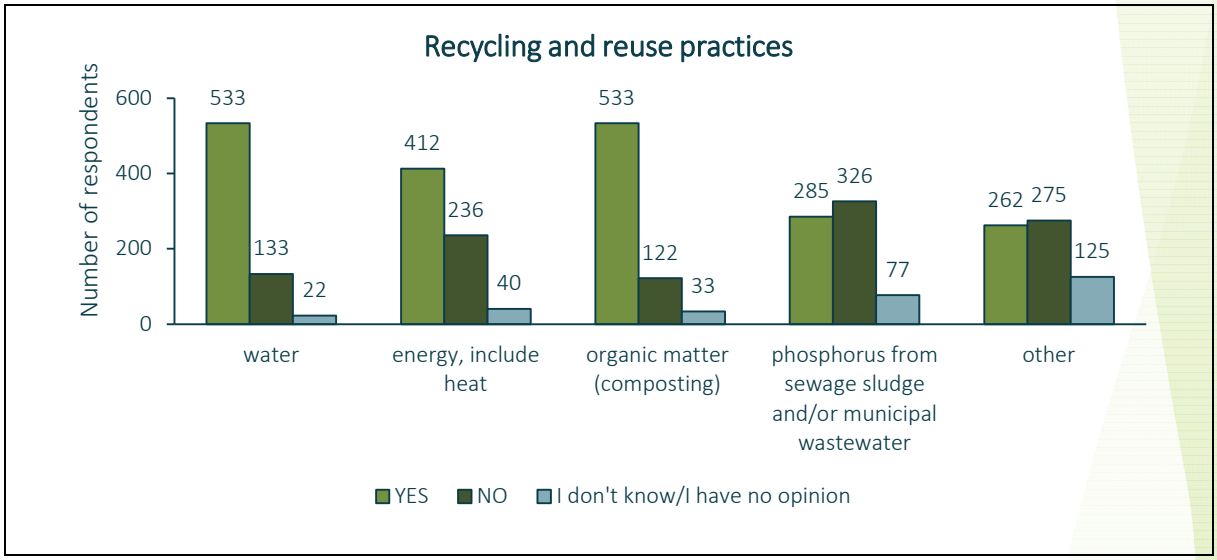


Figure 40. Farmers' recycling and reuse practices.

The farmers were surveyed regarding their practices of reusing or recycling various resources, including water, energy (including heat), organic matter, phosphorus from sewage sludge and/or municipal wastewater, and other reusable or recyclable resources. The findings indicated that water and organic matter were the most commonly recycled or reused resources, with 533 farmers each engaging in these practices. Additionally, 412 respondents reported recycling energy, including heat, while 285 farmers recycled phosphorus derived from sewage sludge and/or municipal wastewater. Furthermore, 262 respondents recycled or reused other resources. However, 133 farmers stated that they do not recycle water, 122 do

not recycle organic matter, 236 do not recycle phosphorus, and 275 do not recycle or reuse other resources. Moreover, a subset of respondents opted not to provide an answer to this question (Figure 40).

The majority of farmers, comprising 58% of the respondents, do not operate animal farms, whereas 41% of the farmers are engaged in some form of livestock farming. A small percentage, 1% of the respondents, did not provide an answer regarding their animal farming practices. Furthermore, 50% of the respondents stated that the intensity of their livestock farming is below 1 livestock unit (LU) per 1 hectare of agricultural land. Around 36% of the farmers reported an intensity range between 1 and 1.5 LU per 1 hectare of agricultural land, while 14% indicated an intensity higher than 1.5 LU (Figure 41).

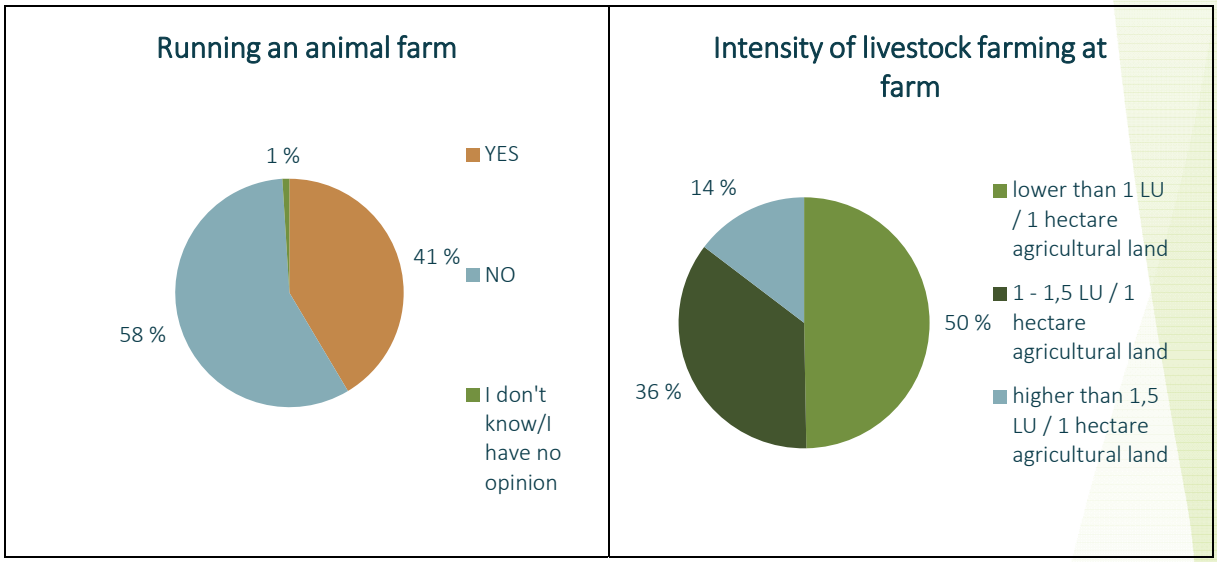


Figure 41. Livestock farming practises among farmers.

Subsequently, the farmers were asked about their current or future utilisation of various materials as fertilisers. The results showed that 389 respondents are currently using or intend to use fertilisers derived from mineral/fossil or synthetic (artificial) resources. Additionally, 330 respondents reported using or being open to using peat as a fertiliser. Moreover, 352 respondents expressed their usage or willingness to use organic raw materials that are not considered waste, such as algae or microorganisms, either in fertiliser form or in their raw form. Furthermore, 520 respondents utilise or are willing to use organic raw materials of animal origin, such as manure or slurry, as fertilisers. In terms of other materials, 271

respondents employ or plan to employ municipal biowaste, while 310 respondents make use of ashes resulting from the incineration of organic waste. Additionally, 211 respondents utilise biochars, 201 respondents utilise struvite, and 515 respondents utilise plant residues (e.g., crop residues, grass) as fertilisers. Furthermore, 253 respondents reported using or being willing to use municipal sewage, and 207 respondents utilise or plan to utilise municipal sewage sludge. Moreover, 291 respondents utilise biodegradable industrial waste (e.g., digestates, sugar molasses, residues from biogas plants) as fertilisers. Lastly, 199 respondents employ or are open to employing other materials as fertilisers (Figure 42).

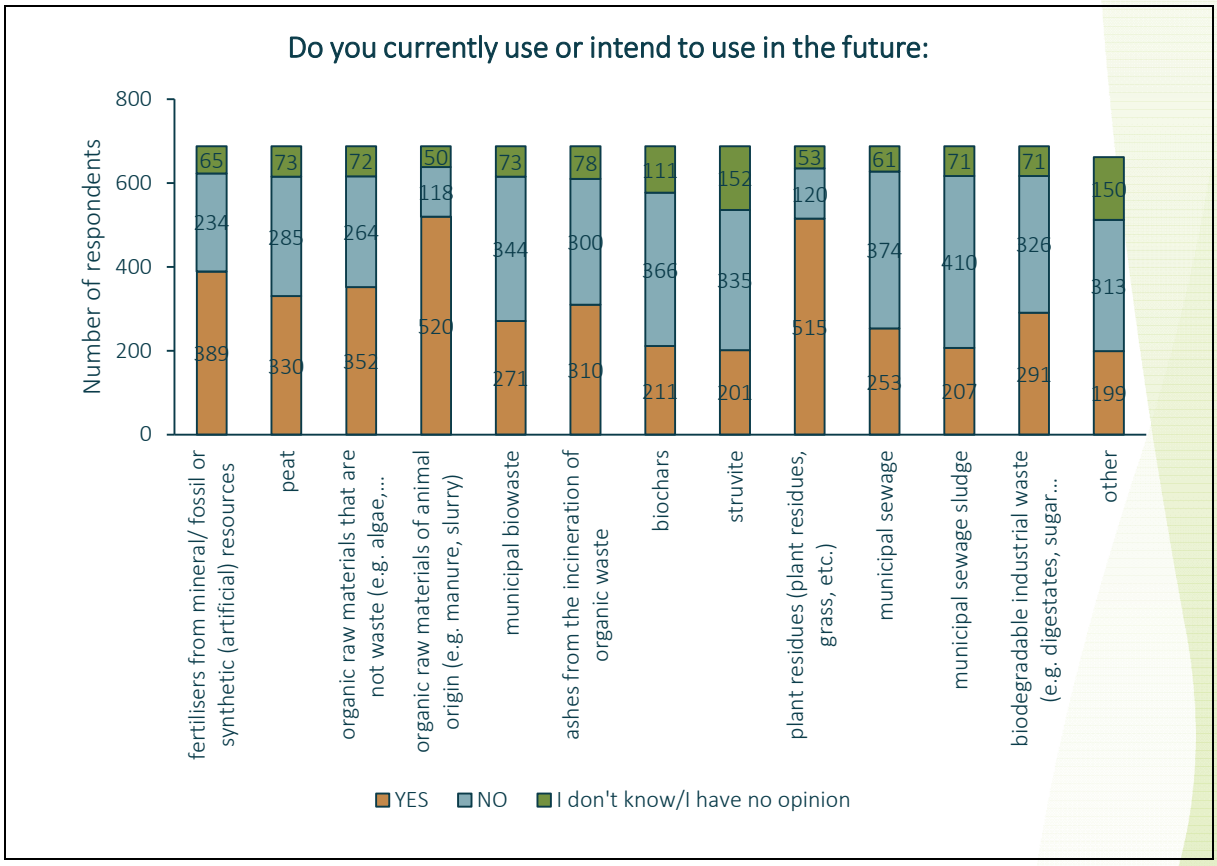


Figure 42. Utilisation of different materials as fertilisers.

Farmers were queried about the factors they perceive as disadvantages or weaknesses associated with specific types of fertilisers (Figure 43). Regarding price, 255 respondents identified it as a disadvantage for fertilisers derived from mineral, fossil, or synthetic substrates. Similarly, 226 respondents considered price a weakness for fertilisers made from organic raw materials (excluding waste). However, only 169 respondents saw price as a

disadvantage for bio-based organic fertilisers from waste. On the contrary, 79 respondents did not view price as a weakness, and 100 respondents had no opinion on the matter. Efficiency, measured by dosage per hectare and biogen concentration, was seen as a drawback by 176 respondents for fertilisers from mineral, fossil, or synthetic substrates. Similarly, 205 respondents identified it as a weakness for fertilisers from organic raw materials (excluding waste). In the case of bio-based organic fertilisers from waste, 159 respondents viewed efficiency as a disadvantage. However, 115 respondents did not perceive efficiency as a weakness, and 128 respondents had no opinion. The specific place of production, such as factories, local companies, or farms, was considered a weakness for fertilisers from mineral, fossil, or synthetic substrates (211 respondents), fertilisers from organic raw materials (excluding waste) (201 respondents), and bio-based organic fertilisers from waste (141 respondents). Knowledge about the production process and its complexity was highlighted as another weakness by farmers, particularly for fertilisers from mineral, fossil, or synthetic substrates (204 respondents), fertilisers from organic raw materials (excluding waste) (186 respondents), and bio-based organic fertilisers from waste (151 respondents). Nonetheless, 114 respondents did not perceive the place and complexity of production as weaknesses, and 135 respondents had no opinion on the matter. Availability of fertilisers could pose a problem, according to 186 respondents, for fertilisers from mineral, fossil, or synthetic substrates. Similarly, 208 respondents viewed it as a weakness for fertilisers from organic raw materials (excluding waste), and 174 respondents identified it as a disadvantage for bio-based organic fertilisers from waste. Conversely, 108 respondents did not consider availability as a weakness, and 114 respondents had no opinion. The absence of a well-known brand or producer was seen as a weakness by 171 respondents for fertilisers from mineral, fossil, or synthetic substrates, by 196 respondents for fertilisers from organic raw materials, and by 134 farmers for bio-based organic fertilisers from waste. However, 127 respondents did not view the lack of a well-known brand or producer as a weakness, and 142 respondents had no opinion. Concerning the effect on soil structure, 215 farmers believed it could be an issue when considering fertilisers from mineral, fossil, or synthetic substrates. Similarly, 192 farmers expressed concern about fertilisers from organic raw materials (excluding waste), and 151

farmers highlighted this concern for bio-based organic fertilisers from waste. Nonetheless, 111 respondents did not perceive it as a weakness, and 107 respondents had no opinion on the matter. 224 respondents highlighted the environmental impact as a disadvantage for fertilisers derived from mineral, fossil, or synthetic substrates. Similarly, 179 respondents perceived it as a weakness for fertilisers made from organic raw materials (excluding waste), while only 142 respondents saw it as a drawback for bio-based organic fertilisers from waste. Conversely, 120 respondents did not consider the environmental impact as a weakness, and 99 respondents had no opinion on the matter. The lack of knowledge about application was identified as a potential disadvantage by 190 respondents for fertilisers from mineral, fossil, or synthetic substrates, by 189 respondents for fertilisers from organic raw materials (excluding waste), and by 159 respondents for bio-based organic fertilisers from waste. However, 129 respondents did not view the lack of knowledge about application as a weakness, and 133 respondents had no opinion. The use of renewable/non-renewable raw materials for fertiliser production was seen as a weakness by 220 respondents for fertilisers from mineral, fossil, or synthetic substrates, by 174 respondents for fertilisers from organic raw materials (excluding waste), and by 145 respondents for bio-based organic fertilisers from waste. Another weakness identified by farmers was the potential impact on consumer and crop health, with 227 respondents expressing concern for fertilisers from mineral, fossil, or synthetic substrates, 186 respondents for fertilisers from organic raw materials (excluding waste), and 141 respondents for bio-based organic fertilisers from waste. Nonetheless, 103 respondents did not perceive the impact on consumer and crop health as a weakness, and 115 respondents had no opinion on the matter. The reliability of fertilisers could be a problem, according to 189 respondents, for fertilisers from mineral, fossil, or synthetic substrates, while 205 respondents viewed it as a weakness for fertilisers from organic raw materials (excluding waste), and 178 respondents identified it as a drawback for bio-based organic fertilisers from waste. However, 110 respondents did not see the reliability of fertilisers as a weakness, and 112 respondents had no opinion. The uncertainty regarding fertiliser content was seen as a weakness by 173 respondents for fertilisers from mineral, fossil, or synthetic substrates, by 219 respondents for fertilisers from organic raw materials, and by 186 farmers for bio-based

organic fertilisers from waste. Conversely, 103 respondents did not perceive the uncertainty of fertiliser content as a weakness, and 122 respondents had no opinion on the matter. The effect on the number of pests and insects was considered an issue by 178, 195, and 152 farmers when considering fertilisers from mineral, fossil, or synthetic substrates, fertilisers from organic raw materials (excluding waste), and bio-based organic fertilisers from waste, respectively. However, 116 respondents did not view it as a weakness, and 124 respondents had no opinion. The labour input required in applying fertiliser was perceived as a disadvantage by 180 farmers for fertilisers from mineral, fossil, or synthetic substrates, by 209 farmers for fertilisers from organic raw materials (excluding waste), and by 142 farmers for bio-based organic fertilisers from waste. Nevertheless, 140 respondents did not see the labour input as a weakness, and 122 respondents had no opinion. Finally, 177 respondents regarded the smell as a disadvantage for fertilisers from mineral, fossil, or synthetic substrates, while 225 respondents saw it as a weakness for fertilisers from organic raw materials (excluding waste), and 209 respondents considered it a drawback for bio-based organic fertilisers from waste. On the other hand, 105 respondents did not perceive the smell as a weakness, and 87 respondents had no opinion on the matter (Figure 43).

The factors that can be perceived as advantages or strengths of specific types of fertilisers are presented on Figure 44. In the case of fertilisers from mineral, fossil, or synthetic substrates, the price was identified as an advantage by 195 respondents. Efficiency, as measured by dosage per hectare and biogen concentration, was considered a strength by 221 respondents. The place of production, such as factories, local companies, or one's own farm, was viewed as a positive aspect by 184 respondents. Knowledge about the production process and application procedures were highlighted by 178 and 190 respondents, respectively. Fertiliser availability was seen as an advantage by 192 respondents, while a well-known brand or producer was regarded favourably by 193 farmers. Furthermore, the positive impact on soil structure, natural environment, consumer and crop health, as well as the reduction of pests and insects, were all seen as advantages by 187, 177, 175, and 175 farmers, respectively. The use of renewable/non-renewable raw materials for fertiliser production was perceived as an advantage by 160 respondents. Reliability and the assurance of fertiliser content were

considered strengths by 206 and 201 respondents, respectively. The labour input required in applying fertiliser was seen as having a positive impact according to 202 respondents, while the smell was regarded favourably by 194 farmers. In the case of fertilisers derived from organic raw materials (excluding waste), the following factors were highlighted as advantages. The price was regarded favourably by 212 respondents, while efficiency, in terms of dosage per hectare and biogen concentration, was seen as a strength by 236 respondents. The place of production, including factories, local companies, or one's own farm, was considered advantageous by 235 respondents. Knowledge about the production process and application procedures were emphasised by 242 and 243 respondents, respectively. Fertiliser availability was perceived as an advantage by 251 respondents, and a well-known brand or producer was seen as a positive attribute by 237 farmers. Additionally, the positive impact on soil structure, natural environment, consumer and crop health, as well as the reduction of pests and insects, were all regarded as advantages by 261, 265, 247, and 234 farmers, respectively. The utilisation of renewable/non-renewable raw materials in fertiliser production was viewed as an advantage by 258 respondents. Reliability and certainty of the fertiliser content were considered strengths by 245 and 244 respondents, respectively. The labour input required in applying fertiliser was seen as having a positive impact by 227 respondents, while the smell was regarded favourably by 210 farmers. When considering bio-based organic fertilisers derived from waste, the following factors were identified as advantages. The price was highlighted as favourable by 180 respondents, while efficiency, in terms of dosage per hectare and biogen concentration, was seen as a strength by 162 respondents. The place of production, including factories, local companies, or one's own farm, was regarded as advantageous by 158 respondents. Knowledge about the production process and application procedures were emphasised by 154 and 155 respondents, respectively. Fertiliser availability was perceived as an advantage by 180 respondents, and a well-known brand or producer was seen as a positive attribute by 127 farmers. Furthermore, the positive impact on soil structure, natural environment, consumer and crop health, as well as the reduction of pests and insects, were considered advantages by 177, 186, 171, and 165 farmers, respectively. The utilisation of renewable/non-renewable raw materials in fertiliser production was viewed as an

advantage by 167 respondents. Reliability and certainty of the fertiliser content were considered strengths by 178 and 155 respondents, respectively. The labour input required in applying fertiliser was seen as having a positive impact by 153 respondents, while the smell was regarded favourably by 159 farmers (Figure 44).

Farmers were surveyed about the primary barriers they perceive in the production of fertilisers from waste. The cost of production, including the expenses associated with pollution removal, leading to high fertiliser prices, was identified as the most significant barrier by 167 respondents. Concerns regarding consumer acceptance of using human excrement (municipal sewage) in food production and the lack of experience and knowledge regarding the use and storage of this type of fertiliser were also highlighted as crucial barriers by 160 and 157 respondents, respectively. Slightly fewer respondents expressed concerns about the source of raw materials for production, resulting in limited fertiliser availability (137 respondents), consumer acceptance issues related to the use of waste-derived fertilisers in food production (135 respondents), high costs associated with transporting and applying fertilisers (134 respondents), environmental pollution caused by their use (133 respondents), and impacts on consumer and crop health (126 respondents). Additionally, concerns about the lower effectiveness and efficiency of this type of fertiliser compared to others were mentioned by 125 respondents. Furthermore, 118 farmers expressed worry about the problem of social trust in new solutions, while 113 respondents identified problems with legal regulations limiting the application and the unpleasant smell of the fertiliser. The lack of acceptance by farmers regarding waste as a source of raw materials for fertilisers emerged as a significant barrier according to 110 farmers, while 72 farmers cited the inability to acquire knowledge about new fertilisers. 37 respondents did not provide an opinion on the matter (Figure 45).

Conversely, the primary motivation driving the production of fertilisers from waste is the imperative to enhance agricultural resilience in the face of climatic conditions such as soil erosion and drought. This driver was emphasised by 252 respondents. Additionally, 247 respondents highlighted the necessity to foster sustainable fertilisation practices, while 231 respondents emphasised the demand from consumers for "bio" products and the growth of

the "bio-products" market. Furthermore, 206 farmers regarded legal regulations that restrict the use of chemical fertilisers as a significant driver, and 187 farmers pointed to the tradition of exchanging raw materials among local farmers. It is worth noting that 54 respondents did not express an opinion on the matter (Figure 46).

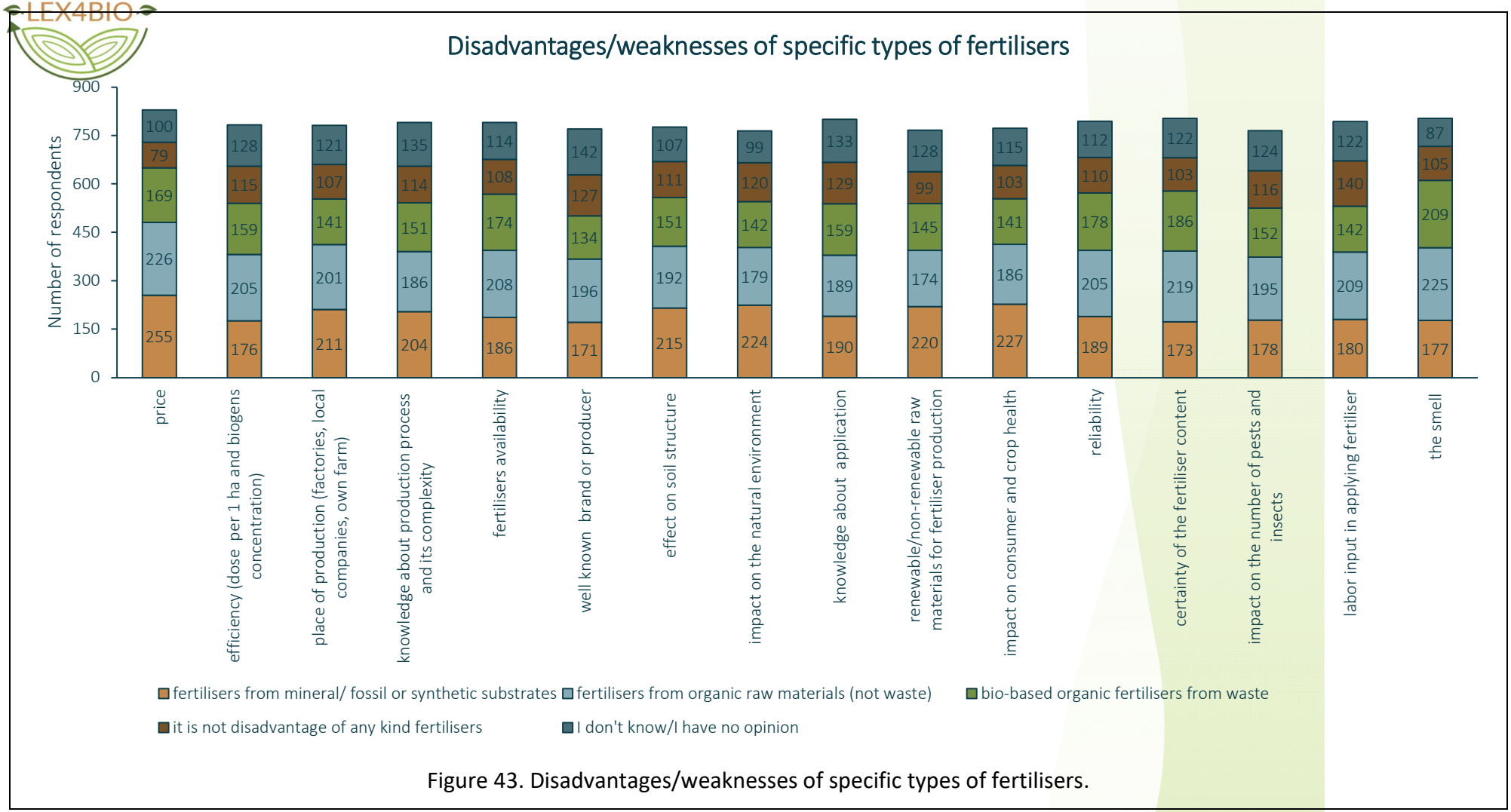


Figure 43. Disadvantages/weaknesses of specific types of fertilisers.

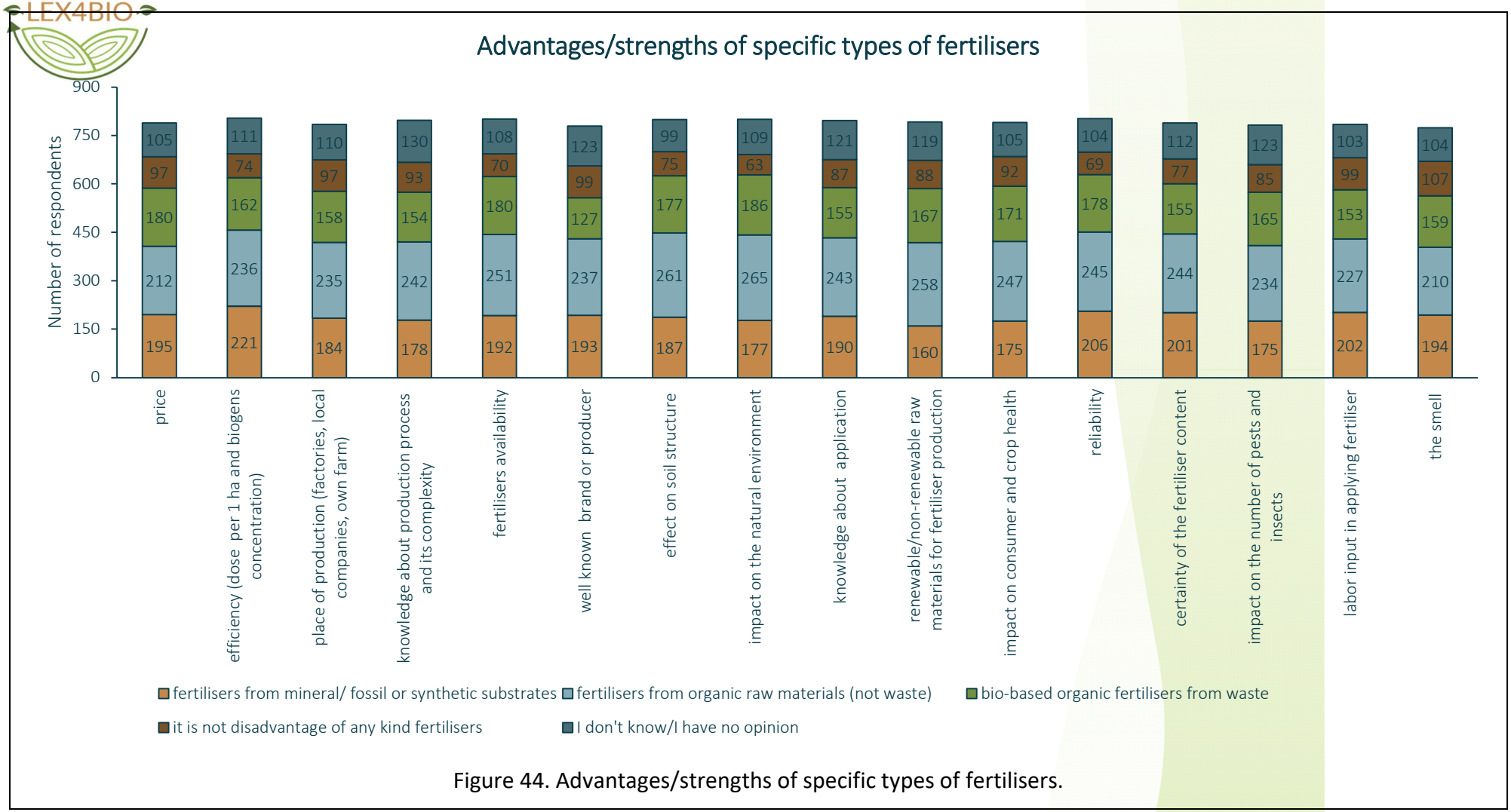


Figure 44. Advantages/strengths of specific types of fertilisers.

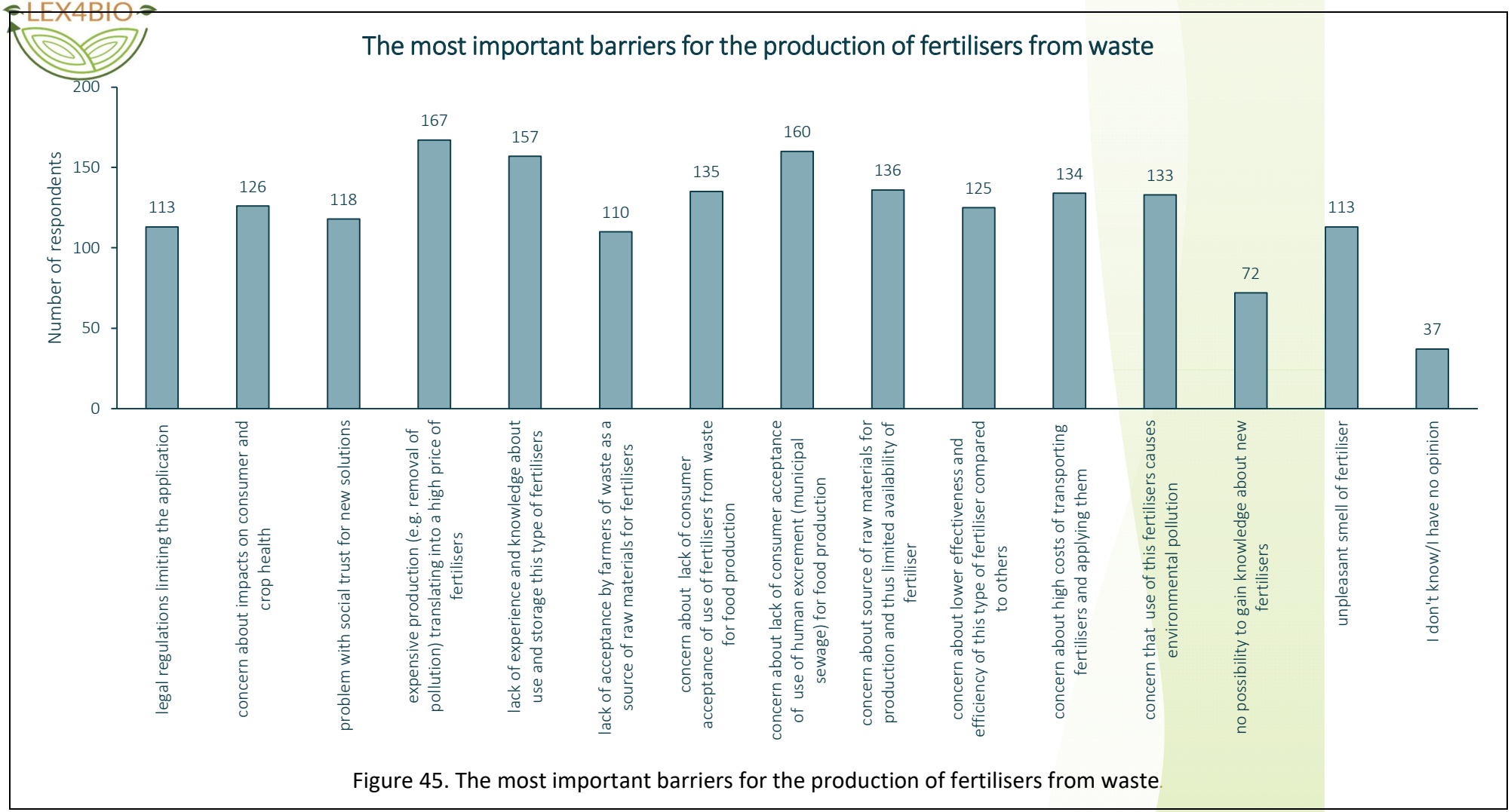


Figure 45. The most important barriers for the production of fertilisers from waste.

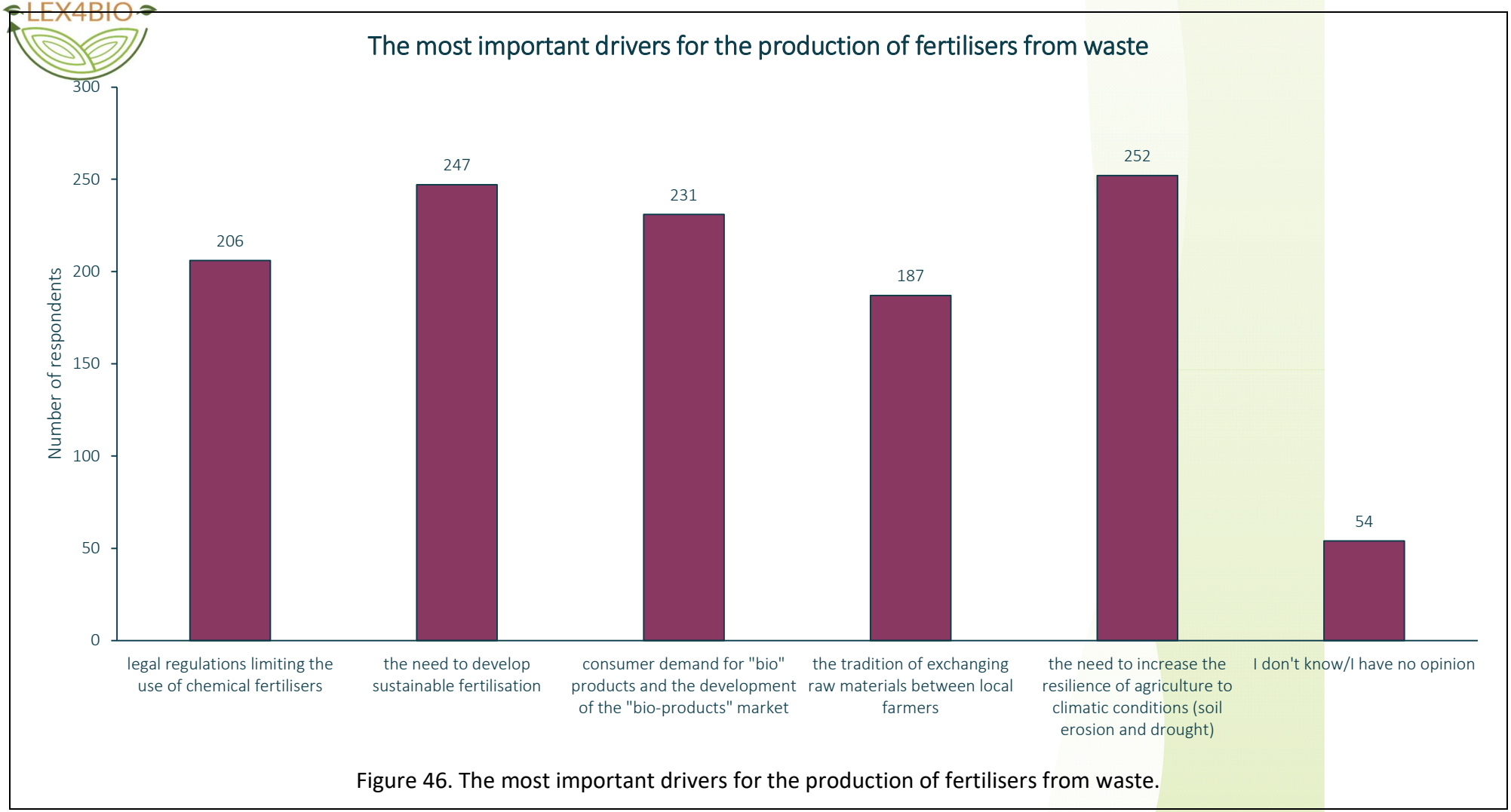


Figure 46. The most important drivers for the production of fertilisers from waste.

The majority of farmers surveyed (258 participants) assert that they possess knowledge regarding the benefits and drawbacks of fertilisers derived from waste. They express that they deem these fertilisers valuable and express their intention to purchase and utilise them. A slightly smaller group of farmers (236 respondents) indicates that they would only use these fertilisers if they were priced lower (while providing the same amount of nutrients) compared to fertilisers made from conventional materials. Additionally, 214 farmers state that they would consider using waste-derived fertilisers only if they were convinced that these fertilisers meet stringent quality standards. In contrast, 142 farmers are generally opposed to using human excrement (municipal sewage) and fertilisers derived from it in agricultural practices, while 53 farmers find it difficult to imagine employing waste-derived fertilisers in agriculture, particularly for food production. Lastly, 56 respondents did not express a definite opinion on the matter (Figure 47).

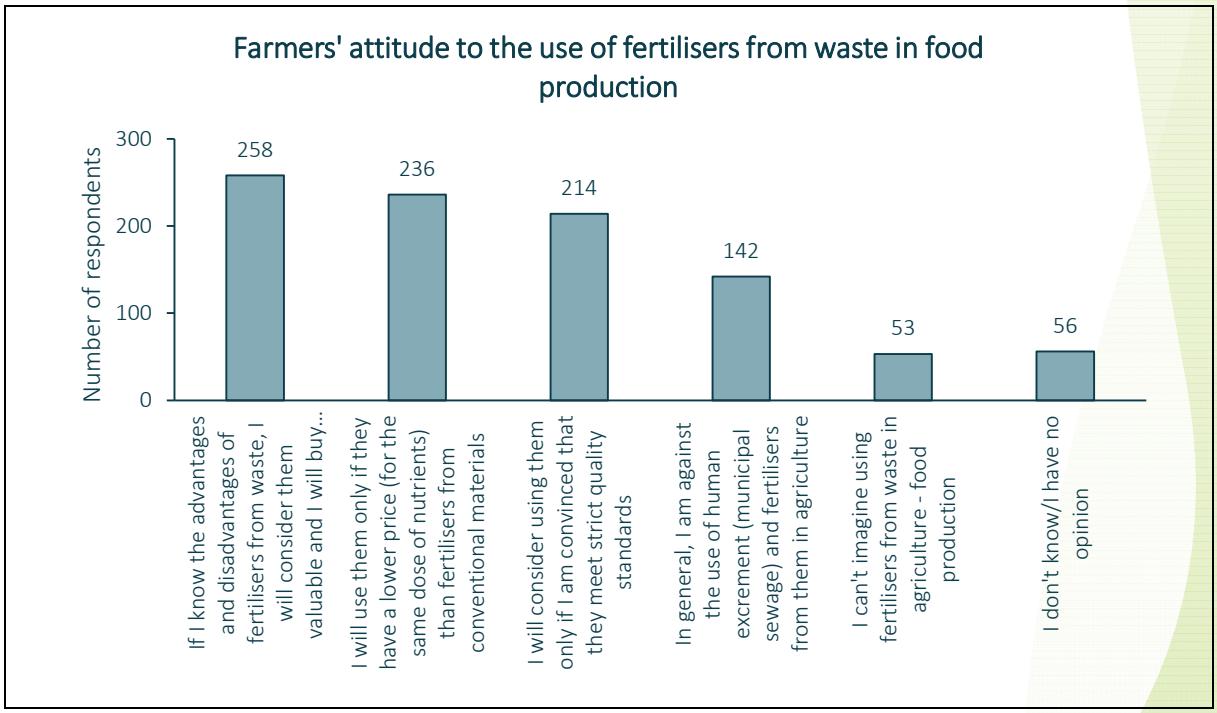


Figure 47. Farmers' attitude to the use of fertilisers from waste in food production.

Following that, farmers were queried about whether the cost of fertilisers derived from waste should vary in comparison to fertilisers produced using conventional materials, assuming both types of fertilisers have identical package weight and nutrient content. The majority of

respondents (431 participants) firmly believe that waste-based fertilisers should be priced lower. On the other hand, 133 individuals hold the view that the prices should be equal irrespective of the origin of the fertilisers, while 62 farmers consider that waste-based fertilisers should be priced higher. Additionally, 62 respondents did not provide a definite opinion on the matter (Figure 48).

Figure 48. Farmers' opinion if there should be a difference between the price of waste-based fertilisers and fertilisers produced with the use of conventional materials.

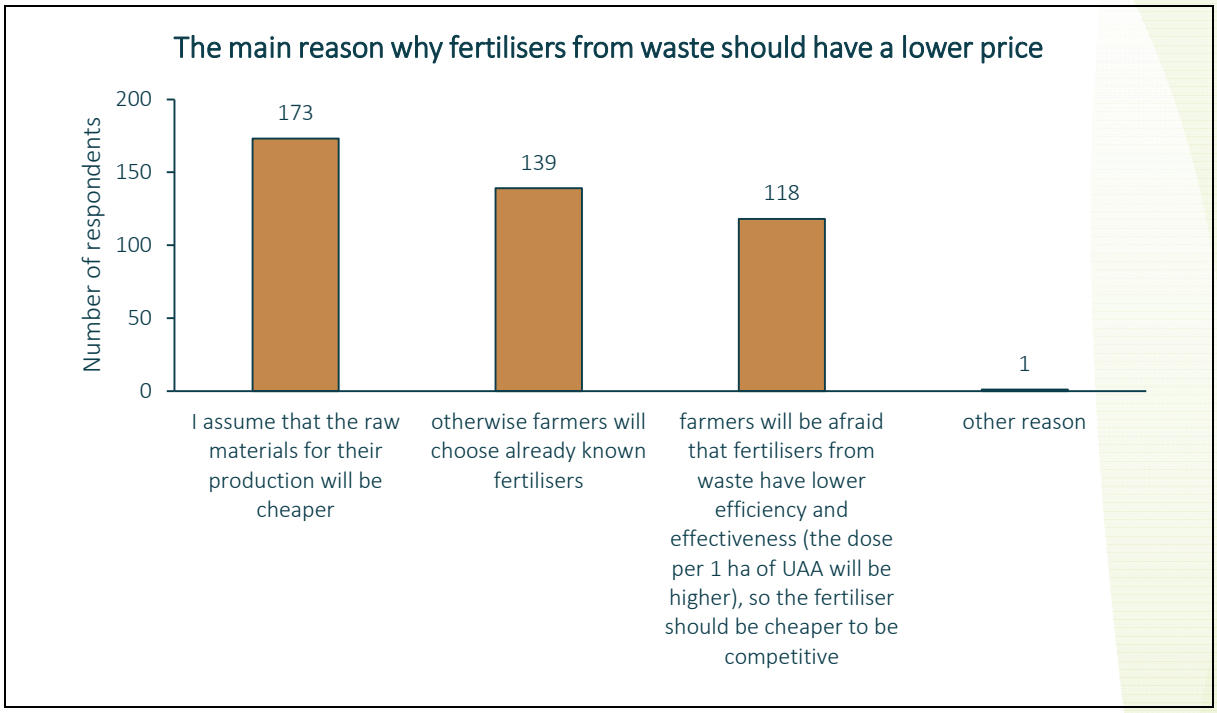


Figure 49. The main reason why fertilisers from waste should have a lower price according to the farmers.

Out of the 431 farmers who expressed the opinion that waste-based fertilisers should be priced lower than conventional fertilisers, 173 of them believe that the raw materials used in their production will be more cost-effective, leading to reduced prices. Additionally, 139 farmers believe that if the prices are not lower, farmers will opt for the already familiar fertilisers. Furthermore, 118 farmers have concerns that fertilisers derived from waste may have lower efficiency and effectiveness, requiring a higher dose per hectare of agricultural land, thus necessitating lower prices to remain competitive. Only one respondent indicated different reasons (Figure 49).

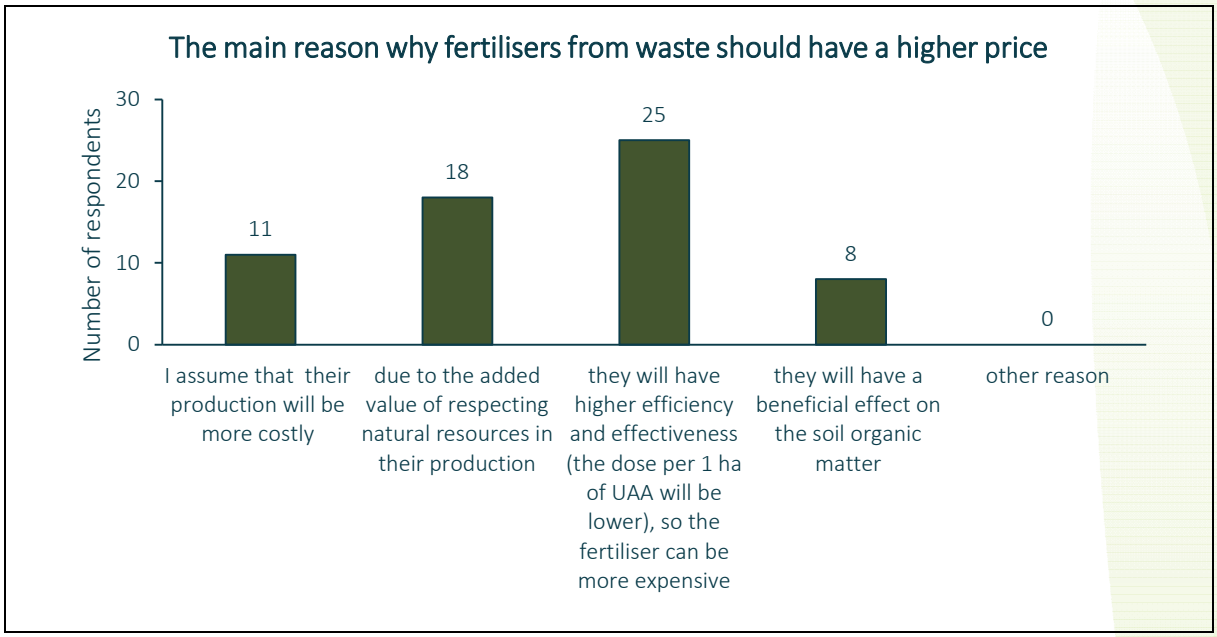


Figure 50. The main reason why fertilisers from waste should have a higher price according to the farmers.

Out of the 62 farmers who previously expressed the opinion that waste-based fertilisers should be priced higher than conventional fertilisers, 25 of them believe that these fertilisers will have greater efficiency and effectiveness, allowing for a lower dose per hectare of agricultural land, thus justifying a higher price. Additionally, 18 respondents highlighted the higher price as a reflection of the added value associated with the sustainable use of natural resources in their production. Moreover, 11 farmers assume that the production process itself will incur higher costs, thereby indicating that the fertilisers should be priced higher to compensate for these expenses (Figure 50).

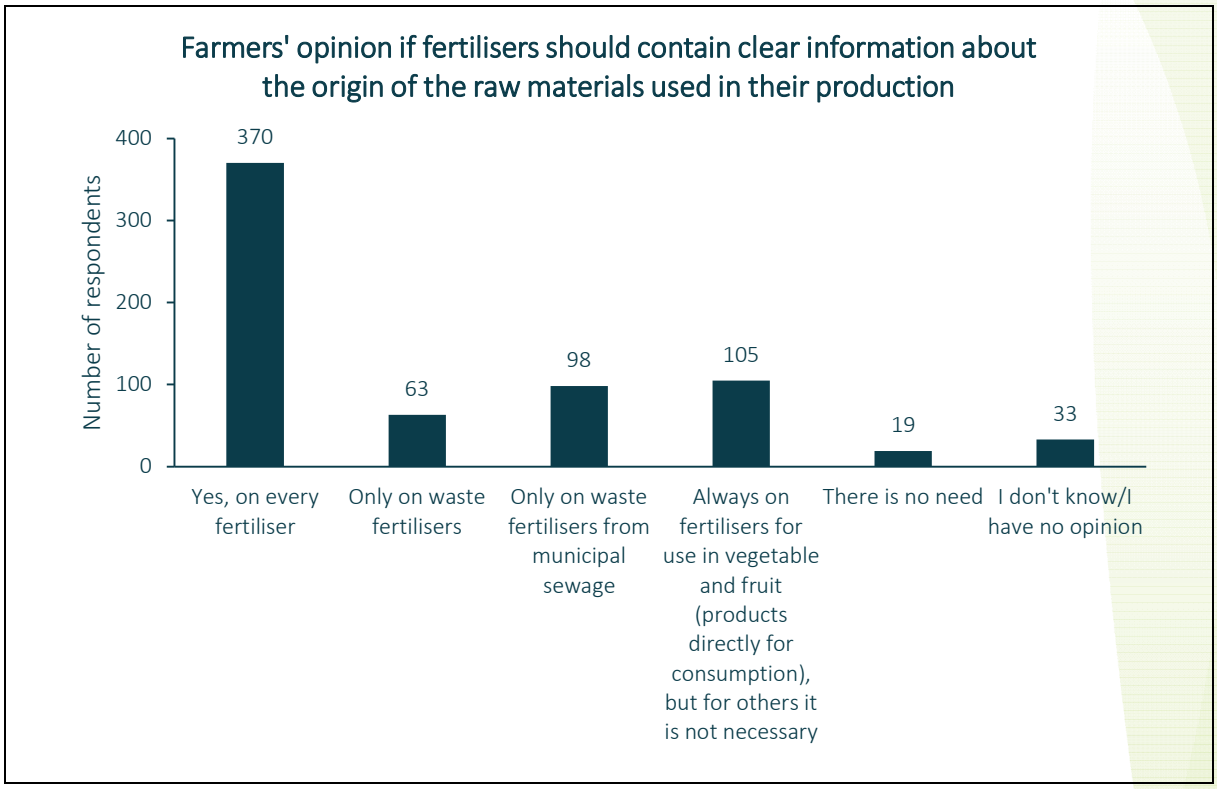


Figure 51. Farmers' opinion if fertilisers should contain clear information about the origin of the raw materials used in their production.

The majority of farmers (370 individuals) hold a strong belief that every fertiliser should include clear information regarding the origin of the raw materials used in its production, regardless of whether the original source was waste materials or not. On the other hand, 105 farmers believe that such information is necessary only for fertilisers intended for use in vegetables and fruits (products directly consumed by humans), while considering it unnecessary for other types of fertilisers. Additionally, 98 respondents express a desire to see information specifically about the origin source of fertilisers derived from municipal sewage, while 63 respondents wish for such information to be provided for all waste-based fertilisers. In contrast, 19 respondents do not see a need for providing this kind of information on any fertilisers, and 33 respondents have no definite opinion on the matter (Figure 51).

Likewise, a majority of farmers (382 individuals) expressed the view that when it comes to fertilisers derived from human excrement (municipal sewage), it is essential for every fertiliser to provide information regarding the origin source of the waste used in its production. Among

them, 210 respondents believe that this requirement should only be applicable to fertilisers intended for use in vegetable and fruit crops (products directly consumed by humans), while considering it unnecessary for other types of crops. In contrast, 52 respondents see no need for providing such information, and 44 respondents do not have a definitive opinion on the matter (Figure 52).

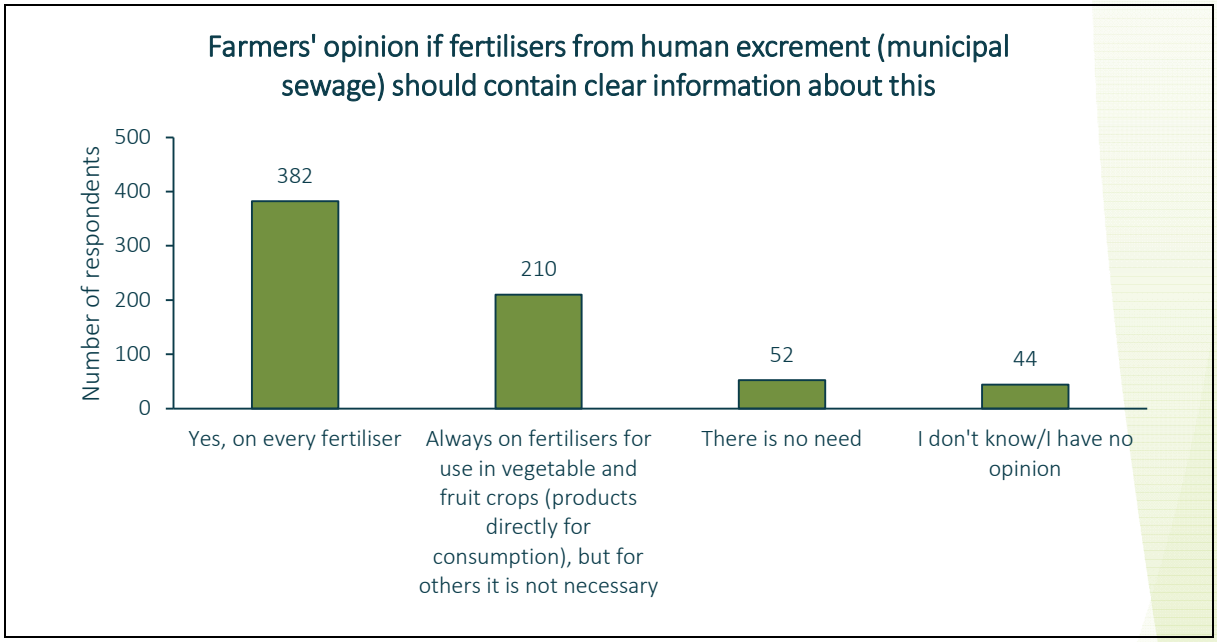


Figure 52. Farmers' opinion if fertilisers from human excrement (municipal sewage) should contain clear information about this.

As per the responses of the 323 participating farmers, it is believed that every food product should include information regarding the fertilisation methods employed during the cultivation process. Among them, 226 respondents recognize the necessity of providing information specifically for products that are directly consumed, such as fruits and vegetables, while considering it unnecessary for other types of food products. On the contrary, 87 respondents do not see a need for providing fertilisation information on any food products, and 52 respondents did not express a definitive opinion on the matter (Figure 53).

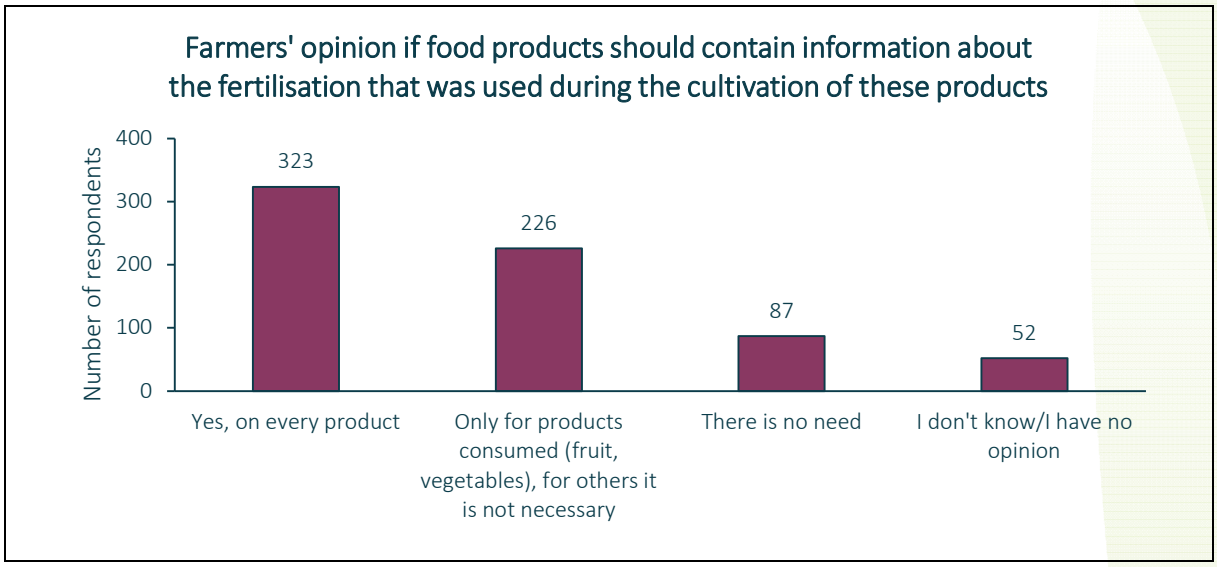


Figure 53. Farmers' opinion if food products should contain information about the fertilisation that was used during the cultivation of these products.

Subsequently, farmers were inquired about whether food products produced with waste-based fertilisers and those produced with human excrement (municipal sewage) fertilisers should include explicit information about the type of fertilisation used. The responses were similar for both questions. For food products cultivated with waste-based fertilisers, 341 respondents believed that information about fertilisation should be provided on every product. Likewise, for food products grown with human excrement (municipal sewage) fertilisers, 373 respondents saw the need for providing fertilisation information on every food product. Additionally, 212 respondents expressed the view that information should be provided only for products directly consumed (such as fruits and vegetables) when they are cultivated with waste-based fertilisers. Similarly, 200 respondents shared the same opinion for food products cultivated with human excrement (municipal sewage) fertilisers. On the other hand, 84 respondents stated that there was no need to provide information about food products fertilised with waste-based fertilisers, while 66 respondents held the same stance for food products fertilised with human excrement (municipal sewage) fertilisers. Furthermore, 51 respondents refrained from answering the question regarding waste-based fertilisers, while 49 respondents chose not to answer regarding human excrement (municipal sewage) fertilisers (Figure 54 and 55).

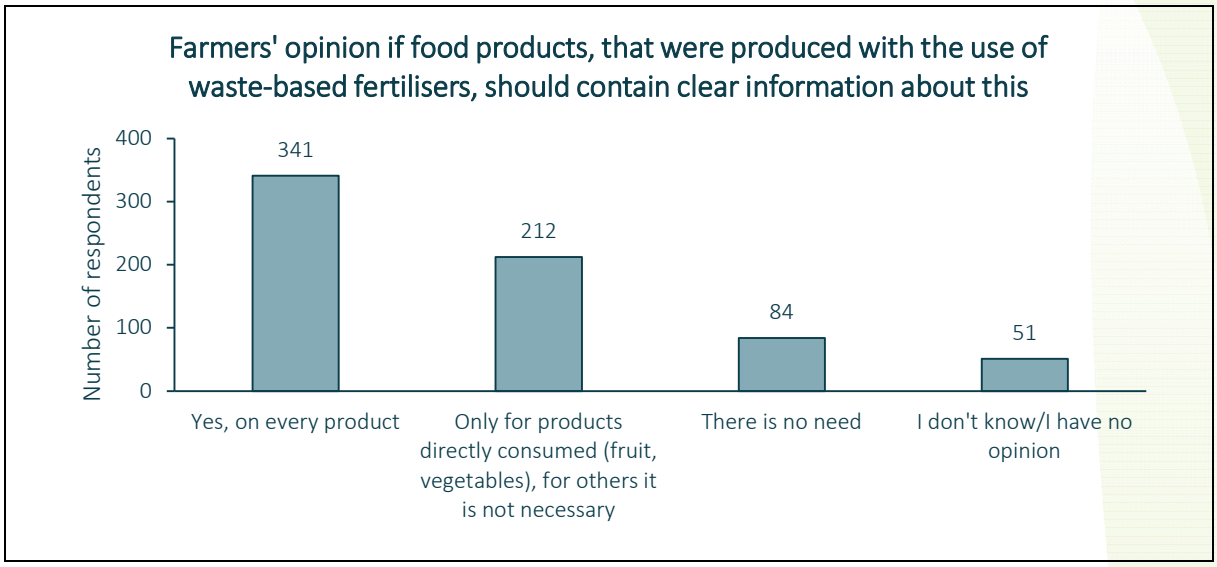


Figure 54. Farmers' opinion if food products, that were produced with the use of waste-based fertilisers, should contain clear information about this.

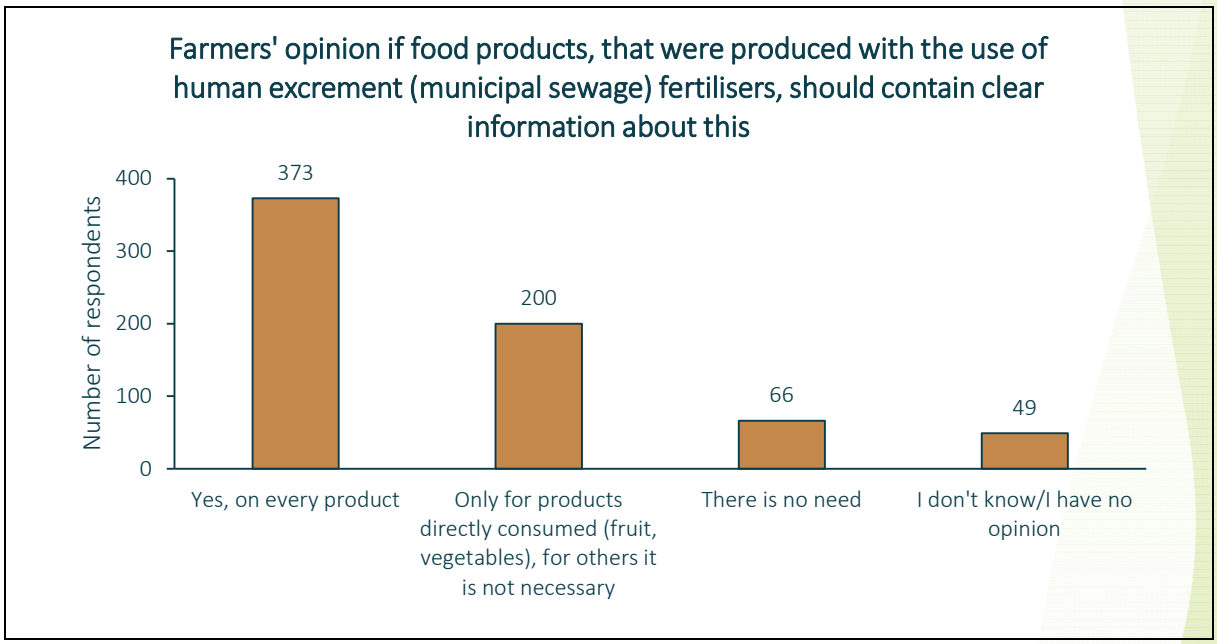


Figure 55. Farmers' opinion if food products, that were produced with the use of human excrement (municipal sewage) fertilisers, should contain clear information about this.

Farmers were surveyed regarding their opinion on the attitude of fertiliser producers towards the utilisation of fertilisers from waste materials. According to the responses, 314 respondents believe that fertiliser producers would engage in the production of fertilisers from waste if it proves to be profitable for them. On the other hand, 210 respondents indicate that producers

are willing to manufacture fertilisers from waste, but this is contingent upon favourable legal changes. Additionally, 160 respondents think that fertiliser producers will consider the quality and quantity of waste substrates, leading them to produce fertilisers from waste to a limited extent or not at all. In contrast, 103 respondents perceive that fertiliser producers are generally opposed to the use of human excrement (municipal sewage) and fertilisers derived from them in agricultural practices. Furthermore, 58 farmers find it difficult to envision using fertilisers from waste in agriculture, especially when it comes to food production. Moreover, 69 farmers chose not to provide an answer to this particular question (Figure 56).

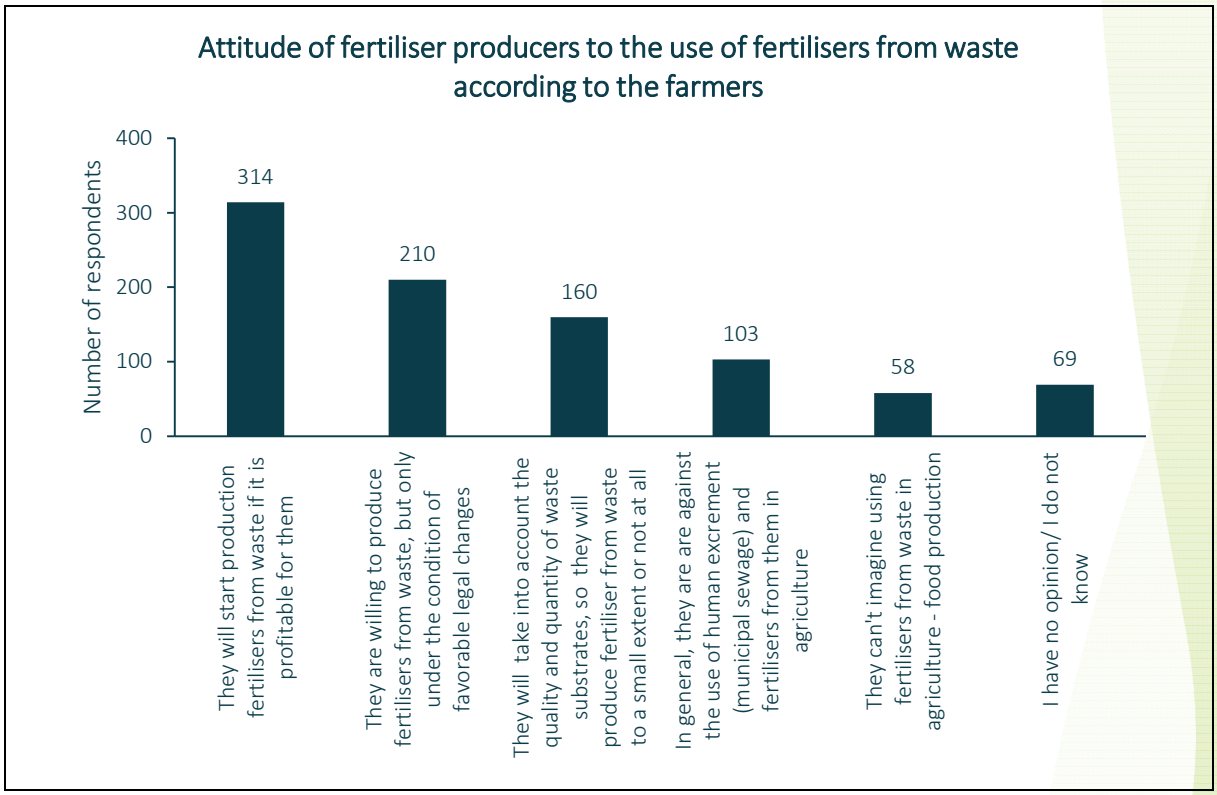


Figure 56. Attitude of fertiliser producers to the use of fertilisers from waste according to the farmers.

In terms of the perspective of food and beverage producers regarding the use of fertilisers from waste, the opinions of farmers varied. According to 225 farmers, there is no valid reason to perceive agricultural produce cultivated using waste fertilisers as different or inferior in any way. On the other hand, 233 farmers believe that food and beverage producers do not pay attention to the specific fertilisation methods employed or the nature of the crops, but rather

prioritise the price and appearance of the crops. Additionally, 179 farmers state that they would consider using such fertilisers only if they were convinced that these products meet stringent quality standards. In contrast, 111 farmers believe that food and beverage producers, in general, hold a negative stance toward the utilisation of human excrement (municipal sewage) and fertilisers derived from it in agricultural practices. Furthermore, 50 farmers cannot envision themselves employing fertilisers from waste in agriculture, particularly for food production. Moreover, 83 respondents did not express a definitive opinion on the matter (Figure 57).

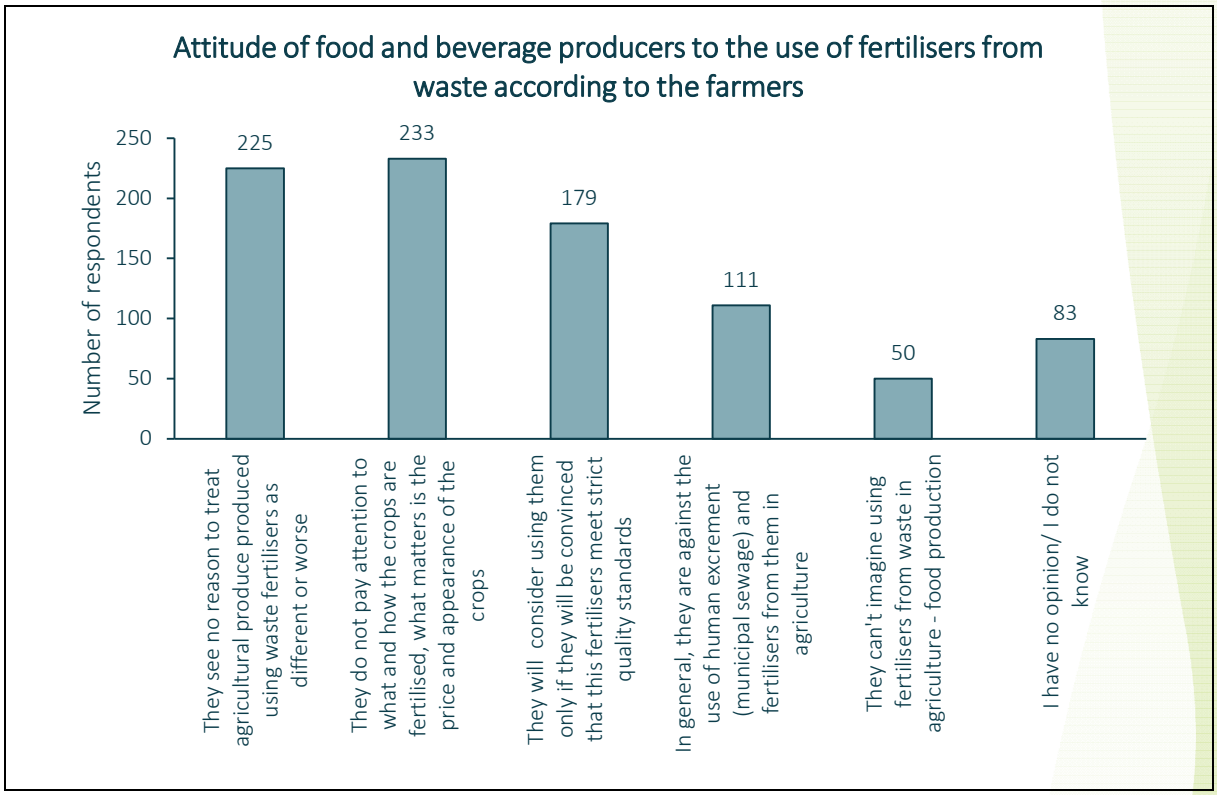


Figure 57. Attitude of food and beverage producers to the use of fertilisers from waste according to the farmers.

Finally, farmers were asked to share their perspectives on the attitude of consumers towards the use of fertilisers from waste materials, based on the farmers' viewpoint. According to the responses, 224 farmers believe that consumers do not pay much attention to the specific fertilisation methods employed or how the crops are fertilised. Instead, consumers prioritize the price and appearance of the products. On the other hand, 185 farmers think that

consumers see no valid reason to treat food produced using waste fertilisers as different or inferior. Furthermore, 179 farmers express that they would consider using such products only if they were convinced that the fertilisers meet stringent quality standards. In contrast, 139 respondents claim that consumers, in general, are opposed to the use of human excrement (municipal sewage) and fertilisers derived from it in agricultural practices. Additionally, 68 farmers find it challenging to imagine consumers embracing the use of fertilisers from waste in agriculture, particularly in food production. Moreover, 67 respondents chose not to provide an answer to this particular question (Figure 58).

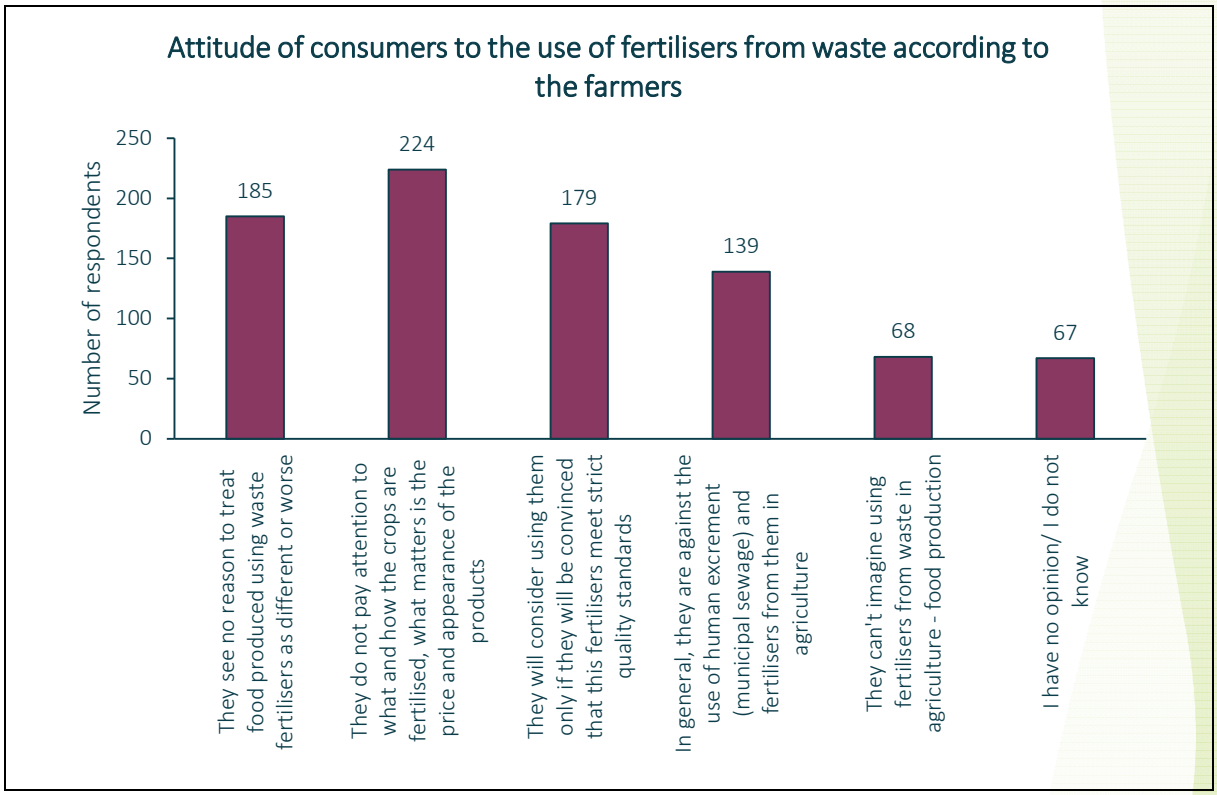


Figure 58. Attitude of consumers to the use of fertilisers from waste according to the farmers.

Summary

The global agricultural sector is facing growing pressure to adopt sustainable practices that minimize environmental impact and enhance resource efficiency. In this context, the replacement of conventional fertilisers with waste-based fertilisers has gained significant attention. Bio-based fertilisers utilise organic materials derived from various waste sources, including municipal sewage, food waste, and agricultural residues, to provide essential nutrients for plant growth. However, the widespread adoption of waste-based fertilisers faces both drivers and barriers that influence farmers' decisions. This summary provides a comprehensive analysis of the drivers and barriers identified in a survey of farmers, consumers and producers, as well as literature review shedding light on the challenges and opportunities associated with the transition to bio-based fertilisers.

The most important drivers of transition:

- Enhancing Agricultural Resilience: The imperative to address soil erosion, drought, and other climate-related challenges emerged as the primary driver among surveyed farmers (252 respondents). Waste-based fertilisers offer potential solutions to these issues, promoting sustainable agricultural practices and building resilience against climatic conditions.
- Sustainable Fertilisation Practices: Farmers recognize the need to foster sustainable fertilisation practices (247 respondents). Waste-based fertilisers contribute to reducing reliance on non-renewable resources, such as mineral fertilisers, and align with the principles of circular economy by converting waste into valuable resources.
- Consumer Demand for Bio-Products: The growth in consumer demand for "bio" or "organic" products (231 respondents) has created a market opportunity for waste-based fertilisers. Consumers increasingly prioritize environmentally friendly and sustainable products, driving the demand for agricultural produce grown with organic inputs.
- Legal Regulations Restricting Chemical Fertiliser Use: Legal limitations on chemical fertilisers (206 respondents) provide incentives for farmers to explore alternative

options such as waste-based fertilisers. These regulations promote sustainable agriculture by discouraging the excessive use of synthetic inputs and encouraging the adoption of environmentally friendly alternatives.

- Tradition of Raw Material Exchange among Local Farmers: In certain regions, farmers value the tradition of exchanging raw materials among local farmers (187 respondents). Waste-based fertilisers facilitate the utilisation of locally available organic resources, strengthening local agricultural systems and fostering community cooperation.

The most important barriers to transition:

- Cost of Production: The cost of production, including expenses associated with pollution removal, leading to high fertiliser prices, emerged as the most significant barrier (167 respondents). Waste-based fertilisers often require additional processing and treatment compared to conventional fertilisers, leading to increased production costs.
- Consumer Acceptance of Waste-Derived Fertilisers: Concerns regarding consumer acceptance of using waste materials, particularly human excrement (municipal sewage), in food production were highlighted as a crucial barrier (160 respondents). Farmers expressed concerns about potential negative perceptions and resistance from consumers towards the use of waste-derived fertilisers.
- Lack of Experience and Knowledge: The lack of experience and knowledge regarding the use and storage of waste-based fertilisers was identified as a significant barrier (157 respondents). Farmers require education and training to effectively utilise these fertilisers and address any concerns related to application methods and potential risks.
- Limited Fertiliser Availability: Concerns about the source of raw materials and limited availability of waste-based fertilisers were mentioned by farmers (137 respondents). Establishing a consistent and reliable supply chain for waste-derived materials poses challenges, limiting access to these fertilisers in certain regions.
- High Transportation and Application Costs: Farmers expressed concerns about the high costs associated with transporting and applying waste-based fertilisers (134

respondents). These additional expenses can make waste-based fertilisers less economically feasible, particularly for farmers operating on smaller scales or with limited resources.

- Environmental Pollution Concerns: Farmers raised concerns about potential environmental pollution caused by the use of waste-based fertilisers (129 respondents). Proper management of application rates and nutrient release is essential to prevent adverse impacts on soil, water, and ecosystems.
- Impacts on Consumer and Crop Health: Farmers highlighted concerns about the potential impacts of waste-based fertilisers on consumer health and crop quality (123 respondents). It is crucial to ensure that the utilisation of waste-derived materials in fertilisers meets rigorous safety standards and does not compromise food safety or consumer well-being.
- Lower Effectiveness and Efficiency Compared to Conventional Fertilisers: Some farmers perceived waste-based fertilisers to be less effective and efficient compared to conventional fertilisers (113 respondents). Addressing this perception through improved product formulation, agronomic practices, and scientific evidence is necessary to build farmer confidence.
- Problems with Social Trust: Farmers expressed concerns about potential social trust issues related to the use of waste-derived materials in fertilisers (106 respondents). Addressing these concerns requires effective communication and transparent information sharing to establish trust among farmers, consumers, and other stakeholders.
- Legal and Regulatory Constraints: Legal and regulatory constraints were identified as a barrier, particularly in developed western countries (94 respondents). Farmers highlighted the need for supportive policies that facilitate the production, marketing, and use of waste-based fertilisers, ensuring they meet safety and quality standards.
- Unpleasant Odour: The presence of an unpleasant odour associated with certain waste-based fertilisers (86 respondents) can be a significant barrier due to its negative

impact on user experience and public perception. Developing odour mitigation strategies is essential to overcome this barrier.

The findings from the survey on the drivers and barriers related to the replacement of conventional fertilisers with waste-based fertilisers provide valuable insights into farmer perceptions. It is evident that cost, consumer acceptance, knowledge gaps, limited availability, transportation costs, environmental concerns, and efficacy challenges are among the significant barriers hindering the widespread adoption of waste-based fertilisers. Addressing these barriers requires collaborative efforts from policymakers, researchers, industry stakeholders, and farmers themselves. To promote the adoption of waste-based fertilisers, targeted awareness campaigns, policy mainstreaming, and support for innovative farmers to conduct on-farm demonstration trials are crucial. Moreover, emphasising the environmental benefits, economic advantages, and the concept of the circular economy can help drive the transition. Education and awareness campaigns are particularly vital in developing countries, where technical, habitual, or cultural difficulties may exist. The findings can inform customer prospecting and segmentation strategies, policy development, and educational initiatives aimed at promoting the adoption of waste-based fertilisers. By capitalising on the identified drivers and addressing the identified barriers, stakeholders can contribute to building a sustainable and resilient agricultural system that minimizes environmental impact and enhances resource efficiency.

References

Adam, C., Peplinski, B., Michaelis, M., Kley, G., Simon, F.-G., 2009. Thermochemical treatment of sewage sludge ashes for phosphorus recovery. Waste Manag. 29, 1122–1128.

Ajmal, M., Ali, H.I., Saeed, R., Akhtar, A., Tahir, M., Mehboob, M.Z., Ayub, A., 2018. Biofertilizer as an Alternative for Chemical Fertilizers. Res. Rev. J. Agric. Allied Sci. 7, 1–7.

Akeredolu, M., Otterpohl, R., Ilesanmi, I., 2006. Attitudes of rural people in Mali and Nigeria to human waste reuse in agriculture. AIAEE 14–19.

Amann, A., Zoboli, O., Krampe, J., Rechberger, H., Zessner, M., Egle, L., 2018. Environmental impacts of phosphorus recovery from municipal wastewater. Resour. Conserv. Recycl. 130, 127–139.

Andrews, J.H., Tommerup, I.C., 1995. Advances in Plant Pathology, ISSN. Elsevier Science.

Barragán-Ocaña, A., del-Valle-Rivera, M. del C., 2016. Rural development and environmental protection through the use of biofertilizers in agriculture: An alternative for underdeveloped countries? Technol. Soc. 46, 90–99.

Bencheva, N., Tepavicharova, M., 2017. Możliwości i postawy rolników w zakresie produkcji biogazu i nawozów naturalnych w Bułgarii. Zagadnienia Ekon. rolnej 3, 92–102.

Bonnichsen, O., Jacobsen, B.H., 2020a. Danish farmers' preferences for bio-based fertilisers – a choice experiment. IFRO Work. Pap.

Bonnichsen, O., Jacobsen, B.H., 2020b. Danish farmers ' preferences for bio-based fertilisers – a choice experiment Ole Bonnichsen Brian H . Jacobsen Juan Tur-Cardona.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8, 559–568.

Case, S.D.C., Oelofse, M., Hou, Y., Oenema, O., Jensen, L.S., 2017. Farmer perceptions and use of organic waste products as fertilisers – A survey study of potential benefits and barriers. Agric. Syst. 151, 84–95.

Chen, X., Zeng, D., Xu, Y., Fan, X., 2018. Perceptions, risk attitude and organic fertilizer investment: Evidence from rice and banana farmers in Guangxi, China. Sustainability 10.

Chojnacka, K., Moustakas, K., Witek-Krowiak, A., 2020. Bio-based fertilizers: A practical approach towards circular economy. Bioresour. Technol. 295, 122223.

Chouichom, S., Yamao, M., 2011. Sustainable Agricultural Development. Sustain. Agric. Dev. 1–4.

Cooper, J., Lombardi, R., Boardman, D., Carliell-Marquet, C., 2011. The future distribution and production of global phosphate rock reserves. Resour. Conserv. Recycl. 57, 78–86.

Cordell, D., Drangert, J.-O., White, S., 2009. The story of phosphorus: Global food security and food for thought. Glob. Environ. Chang. 19, 292–305.

Cordell, D., White, S., 2013. Sustainable Phosphorus Measures: Strategies and Technologies for Achieving Phosphorus Security. Agron. 2013, Vol. 3, Pages 86-116 3, 86–116.

Dahlin, J., Nelles, M., Herbes, C., 2017. Biogas digestate management: Evaluating the attitudes and perceptions of German gardeners towards digestate-based soil amendments. Resour. Conserv. Recycl. 118, 27–38.

Diaz, R.J., Rosenberg, R., 2008. Spreading dead zones and consequences for marine ecosystems. Science (80-.). 321, 926–929.

Duncker, L., Matsegebe, G., Moilwa, N., 2007. The Social/Cultural Acceptability of using Human Excreta (Faeces and Urine) for Food Production in Rural Settlements in South Africa., Water Research Commission.

El Bamiki, R., Raji, O., Ouabid, M., Elghali, A., Khadiri Yazami, O., Bodinier, J.-L., 2021. Phosphate Rocks: A Review of Sedimentary and Igneous Occurrences in Morocco. Minerals 11.

European Commission, 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

European Commission, 2000. Council Directive 2000/60/EC of The European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

European Commission, 2019. Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regula.

Glibert, P.M., Maranger, R., Sobota, D.J., Bouwman, L., 2014. The Haber Bosch-harmful algal bloom (HB-HAB) link. Environ. Res. Lett. 9.

Günther, S., Grunert, M., Müller, S., 2018. Overview of recent advances in phosphorus recovery for fertilizer production. Eng. Life Sci. 18, 434–439.

Gwara, S., Wale, E., Odindo, A., 2022. Behavioral intentions of rural farmers to recycle human excreta in agriculture. Sci. Rep. 12, 1–13.

Hamilton, H.A., Brod, E., Hanserud, O., Müller, D.B., Brattebø, H., Haraldsen, T.K., 2017. Recycling potential of secondary phosphorus resources as assessed by integrating substance flow analysis and plant-availability. Sci. Total Environ. 575, 1546–1555.

Herzel, H., Krüger, O., Hermann, L., Adam, C., 2016. Sewage sludge ash — A promising secondary phosphorus source for fertilizer production. Sci. Total Environ. 542, 1136–1143.

Ipsilantis, I., Karamesouti, M., Gasparatos, D., 2018. Beneficial Microorganisms for the Management of Soil Phosphorus. In: Lichtfouse, E. (Ed.), Sustainable Agriculture Reviews 32: Waste Recycling and Fertilisation. Springer International Publishing, Cham, pp. 53–75.

Jensen, L.S., Thornton, C., Forrestal, P.J., Brandsma, J., Külvet, A., Riiko, K., Kabbe, C., 2016. Mini-paper – End-user requirements for recycled and bio- based fertiliser products (From: https://ec.europa.eu/eip/agriculture/sites/default/files/fg19_minipaper_6_end_user_requirements_en.pdf, accessed date: 29th Sep 2021) [WWW Document].

Koelsch, R.K., Andersen, D., Cortus, E., Johnson, L., Schmidt, A.M., Siek, S.A., Wilson, M.L., 2020. Perceptions of Barriers and Benefits of Manure Use in Cropping Systems. 2020 ASABE Annu. Int. Virtual Meet., ASABE Paper No. 2000753.

Kok, D.J.D., Pande, S., Van Lier, J.B., Ortigara, A.R.C., Savenije, H., Uhlenbrook, S., 2018. Global phosphorus recovery from wastewater for agricultural reuse. Hydrol. Earth Syst. Sci. 22, 5781–5799.

Kurniawati, A., Toth, G., Ylivainio, K., Toth, Z., 2023. Opportunities and challenges of bio-based fertilizers utilization for improving soil health. Org. Agric.

Laborda, E., Del-Busto, F., Bartolomé, C., Fernández, V., 2023. Analysing the Social Acceptance of Bio-Based Products Made from Recycled Absorbent Hygiene Products in Europe. Sustain. 15.

Mariwah, S., Drangert, J.O., 2011. Community perceptions of human excreta as fertilizer in peri-urban agriculture in Ghana. Waste Manag. Res. 29, 815–822.

Martínez, E., Domingo, F., Roselló, A., Serra, J., Boixadera, J., Lloveras, J., 2017. The effects of dairy

cattle manure and mineral N fertilizer on irrigated maize and soil N and organic C. Eur. J. Agron. 83, 78–85.

Müller, B., Finger, D., Sturm, M., Prasuhn, V., Haltmeier, T., Bossard, P., Hoyle, C., Wüest, A., 2007. Present and past bio-available phosphorus budget in the ultra-oligotrophic Lake Brienz. Aquat. Sci. 69, 227–239.

Nesme, T., Withers, P.J.A., 2016. Sustainable strategies towards a phosphorus circular economy. Nutr. Cycl. Agroecosystems 104, 259–264.

Nobile, C.M., Bravin, M.N., Becquer, T., Paillat, J.-M., 2020. Phosphorus sorption and availability in an andosol after a decade of organic or mineral fertilizer applications: Importance of pH and organic carbon modifications in soil as compared to phosphorus accumulation. Chemosphere 239, 124709.

Pacheco, A.L.V., Pagliarini, M.F., de Freitas, G.B., Santos, R.H.S., Serrão, J.E., Zanuncio, J.C., 2017. Mineral composition of pulp and production of the yellow passion fruit with organic and conventional fertilizers. Food Chem. 217, 425–430.

Pahl-Wostl, C., Schönborn, A., Willi, N., Muncke, J., Larsen, T.A., 2003. Investigating consumer attitudes towards the new technology of urine separation. Water Sci. Technol. 48, 57–65.

Pampuro, N., Caffaro, F., Cavallo, E., 2018. Reuse of animal manure: A case study on stakeholders' perceptions about pelletized compost in Northwestern Italy. Sustain. 10, 1–10.

Pappalardo, G., Selvaggi, R., Bracco, S., Chinnici, G., Pecorino, B., 2018. Factors affecting purchasing process of digestate: evidence from an economic experiment on Sicilian farmers' willingness to pay. Agric. Food Econ. 6.

Pathak, A.K., Christopher, K., 2019. Study of socio-economic condition and constraints faced by the farmers in adoption of Bio fertilizer in Bhadohi district (Uttar Pradesh). J. Pharmacogn. Phytochem. 8, 1916–1917.

Perdana, T., Renaldy, E., Utami, H.N., Sadeli, A.H., Mahra Arari, H., Ginanjar, T., Ajeng Sesy, N., Sanjaya, S., Fernianda Rahayu, H., 2018. Farmers behavior on using fertilizer in West Java. AIP Conf. Proc. 1927.

Poikane, S., Kelly, M.G., Salas Herrero, F., Pitt, J.A., Jarvie, H.P., Claussen, U., Leujak, W., Lyche Solheim, A., Teixeira, H., Phillips, G., 2019. Nutrient criteria for surface waters under the European Water

Framework Directive: Current state-of-the-art, challenges and future outlook. Sci. Total Environ. 695, 133888.

Rashid, M.M., Kattou'a, M.G., Al-Khatib, I.A., Sato, C., 2017. Farmers' attitude toward treated sludge use in the villages of West Bank, Palestine. Environ. Monit. Assess. 189.

Romanenkov, V., Belichenko, M., Petrova, A., Raskatova, T., Jahn, G., Krasilnikov, P., 2019. Soil organic carbon dynamics in long-term experiments with mineral and organic fertilizers in Russia. Geoderma Reg. 17, e00221.

Santagata, R., Ripa, M., Genovese, A., Ulgiati, S., 2021. Food waste recovery pathways: Challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment. J. Clean. Prod. 286, 125490.

Savci, S., 2012. An Agricultural Pollutant: Chemical Fertilizer. Int. J. Environ. Sci. Dev. 3, 73–80.

Schmidtbauer, P., 1996. Hinder och möjligheter för källsortering av humanurin – intervjuuntersökning bland lantbrukare, fastighetsförvaltare och boende i Ale kommun (In Swedish). Tech. Rep. no. 5, Swedish Univ. Agric. Sci. Div. Soil Manag.

Schütz, L., 2017. Microbial inoculants: global reliability and specific application in a mixed cropping system on marginal land in India.

Sheidaeia, F., Karami, E., Keshavarz, M., 2016. Farmers' attitude towards wastewater use in Fars Province, Iran. Water Policy 18, 355–367.

Simha, P., Lalander, C., Vinnerås, B., Ganesapillai, M., 2017. Farmer attitudes and perceptions to the re–use of fertiliser products from resource–oriented sanitation systems – The case of Vellore, South India. Sci. Total Environ. 581–582, 885–896.

Smol, M., 2019. The importance of sustainable phosphorus management in the circular economy (CE) model: the Polish case study. J. Mater. Cycles Waste Manag. 21, 227–238.

Smol, M., Adam, C., Anton Kugler, S., 2020. Inventory of Polish municipal sewage sludge ash (SSA) – Mass flows, chemical composition, and phosphorus recovery potential. Waste Manag. 116, 31–39.

Smol, M. 2021. Transition to circular economy in the fertilizer sector—analysis of recommended directions and end-users' perception of waste-based products in Poland. Energies, 14(14), 4312.

Steen, I., 1998. Phosphorus availability in the 21st century : Management of a non-renewable resource. Phosphorus and potassium.

Supaporn, P., Kobayashi, T., Supawadee, C., 2013. Factors affecting farmers' decisions on utilization of rice straw compost in Northeastern Thailand. J. Agric. Rural Dev. Trop. Subtrop. 114, 21–27.

Tur-Cardona, J., Bonnichsen, O., Speelman, S., Verspecht, A., Carpentier, L., Debruyne, L., Marchand, F., Jacobsen, B.H., Buysse, J., 2018a. Farmers' reasons to accept bio-based fertilizers: A choice experiment in seven different European countries. J. Clean. Prod. 197, 406–416.

Tur-Cardona, J., Bonnichsen, O., Speelman, S., Verspecht, A., Carpentier, L., Debruyne, L., Marchand, F., Jacobsen, B.H., Buysse, J., 2018b. Farmers' reasons to accept bio-based fertilizers: A choice experiment in seven different European countries. J. Clean. Prod. 197, 406–416.

U.S. EPA, 2019. The Sources and Solutions: Agriculture [WWW Document].

Vaccari, D.A., 2009. Phosphorus: a looming crisis. Sci. Am. 300, 54–59.

Vaneeckhaute, C., Meers, E., Michels, E., Buysse, J., Tack, F.M.G., 2013. Ecological and economic benefits of the application of bio-based mineral fertilizers in modern agriculture. Biomass and Bioenergy 49, 239–248.

Waqas, M., Rehan, M., Khan, M.D., Nizami, A.-S., 2019. Conversion of Food Waste to Fermentation Products. In: Ferranti, P., Berry, E.M., Anderson, J.R.B.T.-E. of F.S. and S. (Eds.), . Elsevier, Oxford, pp. 501–509.

Wojciechowska, E., Pietrzak, S., Matej-Łukowicz, K., Nawrot, N., Zima, P., Kalinowska, D., Wielgat, P., Obarska-Pempkowiak, H., Gajewska, M., Dembska, G., Jasiński, P., Pazikowska-Sapota, G., Galer-Tatarowicz, K., Dzierzbicka-Głowacka, L., 2019. Nutrient loss from three small-size watersheds in the southern Baltic Sea in relation to agricultural practices and policy. J. Environ. Manage. 252.