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Sustainable Innovations: A Qualitative Study on Farmers' Perceptions Driving the Diffusion of Beneficial Soil Microbes in Germany and the UK

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Abstract: Legislation and consumer preference for more sustainability in the food system require farmers to adopt more stringent sustainably measures without sacrificing business profitability. Scientific and technological innovations, such as beneficial soil microbes for in-field application, may help to achieve this goal, but adoption rates have remained slow thus far. The adopter's perspective is essential to understanding why. This research investigates factors that drive the perceptions of soil microbe solutions across three groups of (potential) adopters as an input to the design of effective communication strategies to accelerate technology diffusion. Factors included in the analyses are *relative advantage*, *compatibility*, *complexity*, *trialability*, *observability* and *image* of applying soil microbes at the farm level. The analysis is based on 28 in-depth qualitative interviews in Germany and the UK, and a focus group discussion in the UK. Data were analysed via content analysis using deductive and inductive processes. Deductive codes were derived from the diffusion of innovations theory. Our results show that soil microbes are still perceived as a challenging product in all three adopter groups, despite the acknowledgement of several advantages and benefits. Predominantly, farmers evaluate the innovation as complex. Furthermore, the observability of the soil microbes was perceived as challenging, which also transfers to the trialability of the innovation. Despite this, in all adopter groups the need for the innovation was recognized.

Keywords: diffusion of innovations; agricultural innovation; farmer perceptions; adopter groups; biostimulants; beneficial soil microbes

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1. Introduction

Population growth and the related rise in consumption increase pressure on land use and contribute to greenhouse gas emissions and biodiversity losses [1]. To ensure and secure the correspondingly growing human need for food, scholars have called for increasing food provision capacity and thus growth in agricultural production [2]. Due to restricted land capacities, growth in agricultural production often means more intensive production. Yet, intensive forms of agricultural production modes are creating unsustainable environmental impacts [3]. Furthermore, some of the necessary agricultural inputs are rendered less effective partly due to increasing resistance by pests or diseases. Additionally, severe weather events induced by climate change are putting more strain on agricultural production.

In parallel, increasingly informed societies also recognize the limitations of intensive agricultural production and their effects of environmental and ecological exploitation, calling for more sustainable production practices [4]. As a result, new regulatory frameworks are being designed to pave the way towards more sustainable agricultural systems. For example, international initiatives related to plant protection products limit the possibilities of input use, thereby increasing the need to develop innovative means of production. With its new Green Deal [5], the EU addresses those needs by promoting solutions based on natural formulas, which may substitute for chemical ingredients [6]. Recently, several acts were endorsed by EU member states which will allow for easier registration and approval of biological plant protection products based on soil microbes [7]. Should these acts come into force, it will make the process of product development easier. One way to address this demand for sustainable food production is by adopting more sustainable innovations on the field-level application.

1.1. Background on Soil Microbes in Agriculture and Related Challenges

In the fields of plant protection and pest suppression, products based on beneficial soil microbes were identified as a potentially valuable contribution to sustainable agricultural production [8,9]. "Beneficial microbes" is an umbrella term for various microbes that can form a relationship with the plant and, consequently, create beneficial effects for the plant through biological processes. The promising beneficial microbes are plant growth-promoting rhizobacteria (PGPR), arbuscular mycorrhizal fungi (AMF) and nitrogen-fixing bacteria, among others [10,11]. For improved readability, the term "soil microbes" is used to refer to beneficial soil microbes, precluding harmful soil microbes. One way to apply these microbes to the field is via so-called biostimulants. Jardin [12] defined biostimulants as "substances and materials, with the exception of nutrients and pesticides, which, when applied to plant, seeds or growing substrates in specific formulations, have the capacity to modify physiological processes of plants in a way what provides potential benefits to growth, development and/or stress response" (p. 27). Drobek et al. [6] provided an overview of several sources of biostimulants and the effects they can achieve. Among others, they mentioned effects on growth and yield, protection against stress, increase in soil fertility and increased resilience towards infections [6]. On the farm level, a product based on soil microbes can take various forms. Bashan et al. [13] identified five carriers of inoculants of PGPR: soils, waste plant materials, inert materials, plain microbial cultures, and liquid inoculants. Concerning the application of AMF, external factors, such as ploughing, or application of other inputs, needs to be considered for application [14]. As challenges for an efficient and sustainable usage of microbial inoculums on the field, Ray et al. [15] mention potential obstacles, e.g., previous land-use, other microbiota present in soils or agricultural management practices, such as tillage. The application of AMF and its functions are manifold; these include increasing nutrient and water uptake, resistance to root pathogens, or strengthening resistance to stress factors [16]. The application of mycorrhizal fungi is tightly connected to sustainable agriculture because the fungi itself thrives better under conditions of sustainable farming than under high-intensity conventional agriculture [17]. Chen et al. [14] showcased how offers of products based on AMF rose over the last three decades in Europe. Between 1990 and 2017, the number of companies producing AMF increased from 10 to 75 [14]. This highlights the manifold opportunities and growth potential offered by soil microbial biostimulants.

Through the development of "next-generation sequencing" (p. 3), researchers from the field of biology could contribute new insights which advance the understanding of microbes and their potential for field usage [15]. These advances added to other promising results regarding soil microbes over the last 30 years; however, limitations to establish a successful application as a measure for plant protection in commercial agriculture still exist [10]. Pineda et al. [18] highlight how microbes can be less effective when applied with conventional agricultural management practices; additionally, their effects may only appear when exposed to external stress. Moreover, Rouphael and Colla [11] identified past as well as future challenges of plant biostimulants, but because of the high potential in research advancements, the authors argued and identified possibilities for what they call the "next generation of biostimulants" (p. 4). Drobek et al. [6], while highlighting the wide potential and positive impact which biostimulants can trigger, also point to the lack of use of this innovation by farmers; the authors attribute insufficient knowledge and specificity of application conditions as the major barriers for farmers. Assuming the potential of this technology is as large as experimental studies suggest, research must be centred on farmers' perspectives. This will enable us to gain insights into potential barriers and facilitators as well as promising diffusion processes to develop measures that facilitate the adoption process at the farm level.

1.2. Research Approach

Innovations can shape and support an overall transition towards more sustainable agricultural practices. However, adoption is a prerequisite for the success of an innovation. According to Rogers' [19] diffusion of innovation theory (DIT), the process of adoption and diffusion can be captured in a bell-shaped curve, differentiating between innovators and early adopters of innovation at the beginning of the diffusion process, all the way to the laggards at its end. Early adopters and their experiences crucially shape the diffusion of innovations, which is also influenced by other stakeholders who manage knowledge and information c.f. [20]. Rogers [19] identified the characteristics of the innovation and the social network of the potential adopters as key aspects influencing diffusion. In line with the DIT, this research looks at the perceived innovation traits of soil microbes from farmers' perspectives, comparing specific farmer groups at different points on the diffusion curve. In this research, farmers were clustered into three groups: non-adopters, dis-adopters, and adopters. Due to the new and unknown aspects that are inherent to innovations, an open, explorative, and qualitative research approach has been selected to gain insights into factors influencing the (non)adoption of soil microbes. More specifically, this research explores which innovation traits appear to be crucial for adopting innovations based on soil microbes and what farmers' perceptions are regarding those traits. Additionally, communication channels important for innovation diffusion are investigated, as they can play an important role in shaping farmers' perceptions and drive innovation diffusion. Lastly, by implementing the DIT, we gain insights as to whether the theory fits and is reflected in farmers' discussions, indicating the theory's relevance and meaning to understanding farmers' perceptions of soil microbes.

2. Theoretical Framework

To explore the perception and willingness to adopt an innovation, such as soil microbes, this study applies an extension of the DIT by Rogers [19] as its theoretical framework. According to Rogers [19], the uptake and diffusion of innovations is influenced by the *relative advantage* of an innovation compared to the status quo, its *compatibility*, *complexity*, *trialability* and *observability*. A number of other studies also focused on identifying attributes influencing the uptake and diffusion of an innovation (Table A1). Several of those are already covered by Rogers' [19] DIT and are therefore not included as additional determinants in this study. This holds for the four attributes suggested by Tornatzky and Klein [21]: *cost*, *profitability*, *divisibility*, and *communicability*. *Cost* and *profitability* are already captured in the trait *relative advantage* of the DIT. *Divisibility*, as Tornatzky and Klein [21] note, is closely linked to Rogers' [19] innovation trait *trialability*. *Communicability* is related to *observability*, because *observability* as defined by Rogers [19] (p. 244) also captures the communication about the innovation. The attribute *voluntariness of use* has been recommended by Moore and Benbasat [22]. However, it is not applicable to our case because no political or social pressure specifically concerning the adoption of soil microbes exists. The attribute *image* proposed by Moore and Benbasat [23] is not considered in Rogers' [19] framework. Tornatzky and Klein [21] picked up a similar attribute referring to it as *social approval*. We extend the framework by considering this dimension in addition to the five innovation traits suggested by Rogers [19]. Table A1 presents an overview of the factors influencing the uptake and diffusion of innovations as derived by Rogers [19] and other sources.

The key premise underlying and justifying the relevance of the DIT is the assumption that innovation traits can influence the acceptance and consequently the adoption of an innovation [24,25]. Kuehne et al. [26] describe the DIT by Rogers [19] as a key theory that captures factors influencing adoption. According to the authors, the value of the theory is that it allows for a conceptualisation of adoption, but its focus is less on prediction through quantitative approaches.

Besides innovation traits, innovation diffusion is shaped by communication networks. Nutley et al. [27] defined and categorized sources of communication into: (1) interpersonal communication channels and (2) mass media communication channels. In this study we focus on interpersonal communication to grasp the network around the farmer which is important for diffusion.

3. Material and Methods

By definition, an innovation entails a new subject or idea; therefore, research dealing with innovations requires a suitable methodology that can explore the new and unknown. Tornatzky and Klein [21] highlighted that the perceptions of the adopter should be at the centre of research which attempts to capture innovation characteristics. An open and qualitative research approach facilitates the exploration of such a new sustainable technology. Accordingly, our analysis is based on in-depth, qualitative interviews and a focus group discussion, to gain insights into farmers' perceptions and the mechanisms driving farmers' (intentions of) adoption with respect to agricultural innovations, such as soil microbes.

Supplementary Materials, such as the consent form, interview guide, and more materials on the results can be found here https://osf.io/xdn3z/ (accessed on 9 December 2021, last edits on 9 May 2022).

3.1. Sampling and Participants

Qualitative research is often based on small samples. However, in qualitative research, the size of the sample or its representativeness matters less than the depth and breadth of individual opinions that are covered [28]. Corbin and Strauss [29], who largely coined grounded theory, argue for a "representativeness of concepts, not of persons, that is important" (p. 421). The sampling strategy of our study was based on a snowball sampling approach through partners of the EU-financed MiRA (Microbe-induced Resistance to Agricultural Pests) project in Germany and the UK. As the study focuses on potatoes, locations with relatively high potato production in the area were the starting points for farm visits and interviews with farmers and other stakeholders from the potato industry in both countries. In total, 51 participants from Germany and the UK took part, consisting of 36 farmers and 15 agricultural advisors and other stakeholders. The insights gained from interviews with agricultural advisors and other stakeholders close to potato production were used to triangulate the insights from farmers and put them into wider perspective. However, this study presents the results from the farmer sample only. Overall, our sample size is in line with previous studies. In a review on publications which deal with soil health practices in the United States, the sample sizes of the evaluated qualitative studies ranged from 5 to 17 participants [30]. The analysis of sample size in qualitative research by Mason [31] showed that average sample size in selected studies was 28 and Morse [32] and Bernard [33] identified that a sample size between 30 and 50 is a suitable sample size to reach saturation in qualitative research.

Interviews between the participants and the first author were conducted face-to-face. In a few cases, interviews were conducted with two farmers together or other family members were present during the interview. Most interviews were held in situ on the farms or at the locations of contact, such as event sites. One focus group was organized with farmers from an agricultural advisory group in Scotland. All interviews and the focus group were audio recorded. Before the start of the recording, the interview participants were informed about the research project and the purpose of the interview, and their consent was collected via signature on a consent form.

3.2. Interview Guide and Transcripts

Semi-structured interviews were conducted with 36 farmers applying an interview guide. Semi-structured interviews allow the interviews to develop organically, giving more room and flexibility to each respondent's unique background, circumstances, and perspectives. At the same time, it enables the interviewer to address all topics of relevance to the research. No pre-defined categories or quantitative measurements are restricting the participants in their expression, thus, facilitating the expression of subjective views and experiences [34].

The interviews focused on innovations based on soil microbes and farmers' related perceptions, adoption processes, information, and experiences. The interview guide did not follow a specific theoretical framework, but rather explored farmers' perceptions of the technology and their association or experience with respect to its adoption. This way, a pre-defined theoretical framework that might influence the interviewer, the interview and the created material could be avoided.

All interviews and the group discussion were transcribed. Intelligent verbatim transcripts formed the basis for the content analysis. To ensure the anonymity of all participants, we replaced identifying information, such as names and places, thus creating a pseudonymisation of the transcripts.

3.3. Codebook and Content Analysis

The transcribed interviews were analysed through content analysis. Content analysis tries to capture meaning which is inherent in a text given a particular context [35]. In this case, the text was created in the context of interviews which addressed perceptions and experiences with innovations. First, the nodes for the content analysis were informed deductively by an extension of Rogers' [19] DIT as derived in Section 2, see Stage 1 in Figure 1. Second, the first author tested the codebook with all transcripts; with categories and subcategories arising from data, the framework and codebook were extended inductively. This way, a mixed coding method was applied, using deductive and inductive coding strategies. After the development and adjustment of the template codebook, a random selection of four transcripts was coded by three coders. Divergence in coding was discussed, and minor adjustments implemented. A second round of test coding was conducted with another random selection of two transcripts, and subsequent adjustments were implemented. All three coders conducted the final coding, with each transcript being coded by two coders separately (Stage 5 in Figure 1). The data analysis was carried out utilising the software NVivo 13. The final codebook applied is depicted in Table A2. Once the transcripts were coded according to the codebook, subthemes were identified within each code inductively. Attride-Stirling's [36] thematic analysis approach informed the formation of subthemes: topics that arose at each node were grouped according to an overarching common theme and formed a new subtheme. One coder developed the sub-themes for some of the nodes, another coder screened these sub-themes and the first author finally merged them together. With these sub-themes, the number of occurrences was captured in terms of the number of coded statements. Percentages of the frequency of mentioned statements per code were calculated from the total amount of coded statements per group. Similar to Jabbour et al., it will be assumed that higher occurrences of concepts or subthemes indicate a greater importance of said concept in the decision or adoption process [37].

On the one hand, the results provide insights about the applicability of the suggested framework for the investigated innovation, which reflects the theory-driven deductive approach. On the other hand, results from the sub-themes highlight in more detail the perceptions and perceived barriers and opportunities of the innovation. These themes can inform future communication strategies towards potential adopters.

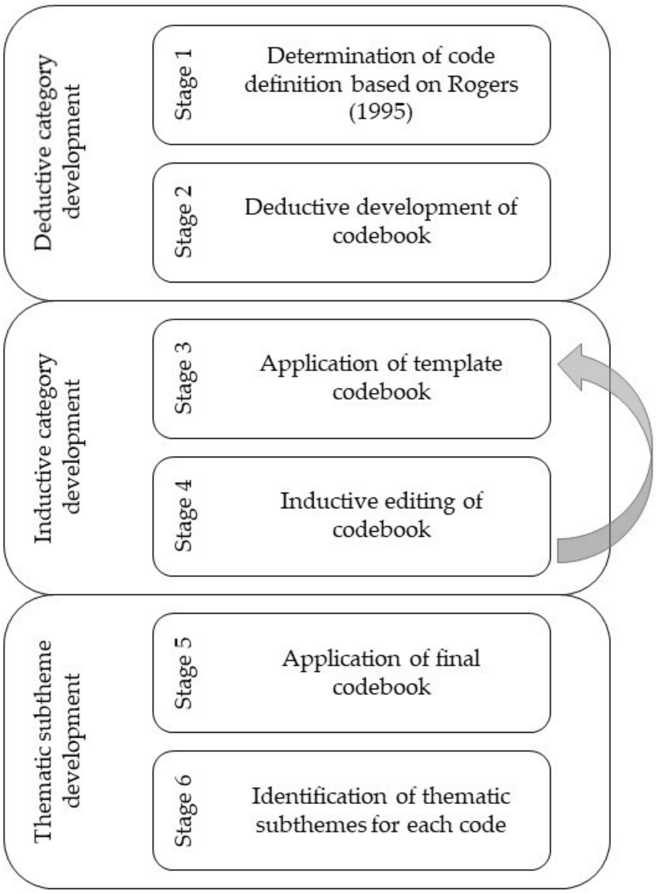

Figure 1. Stages of the applied coding process and development of thematic subthemes.

3.4. Reliability of the Coding

Inter-coder reliability was calculated using Cohen's Kappa which provides a common measure of the reliability of two independent assessments. Values below 0.40 are considered to represent poor, values between 0.40–0.75 moderate, and values above 0.75 good reliability [38]. Cohen's Kappa between the principal coder and "coder A" is 0.67 and between the principal coder and "coder B" 0.61, thus the overall intercoder reliability can be evaluated as moderate, and therefore sufficient. These values were calculated after the first complete round of coding. Subsequently, discussion among all coders with respect to codes of disagreement allowed for small adjustments.

4. Results

4.1. Overall Sample and Adopter Groups

The majority of participants were male, reflecting the reality of the agricultural sector, where more than 90% of farmers in Germany and 82% in the UK are male [39,40]. The share of organic farmers in our sample—36% for the German, and 5% for the UK sample—is large compared to the overall farmer populations of the respective countries. In 2020, 13% of agricultural producers in Germany [41] and about 2% of farmers in the UK [42,43] farmed organically. The farm sizes of the German sample range between 68 and 945 hectares and thus lie well above the average German farm size of 63 hectares in 2020 [44]. In Scotland, the average farm size was 112 hectares in 2019 [45], while the farm size in our sample ranges between 161 and 2400 hectares, thus also comprising mostly larger farms. An overview of demographic statistics can be found in Table 1.

Table 1. Data collection and sample descriptive statistics by geographical samples (percentage from total, n = 36).

		Germany	UK
Data collection period		10–11/2019	02–03/2020
Participants		n = 14 (39%)	n = 22 (61%)
Interview duration		32–76 min	30–68 min
Mode of production	Conventional production	n = 9 (25%)	n = 21 (58%)
	Organic production	n = 5 (14%)	n = 1 (3%)
Hectare (range)	Smallest farm size	68 hectares	161 hectares
	Largest farm size	945 hectares	2400 hectares
Age range		27–63 years old	22–77 years old
Gender	Male	n = 14 (39%)	n = 19 (53%)
	Female	n = 0	n = 2 (6%)

Before investigating attributes relevant to the perception and potential adoption of biostimulants and soil microbes, we investigated farmers' knowledge and experience with respect to these innovations. Thus, all participants were asked whether they had any knowledge or experiences and had adopted biostimulants or similar innovations on their farm. Eighteen of thirty-six farms had no experience at all, whereas the level of adoption and the innovative products applied varied among the ones with experience. Montes de Oca Munguia et al. specifically referred to an adoption process as a fluent pathway with different adoption status [46]; they defined dis-adopters as those who had used the innovation in the past but stopped using it. Based on their indicated level of experience the participants were assigned to one out of three adopter groups: (1) no experience, non-adopter, (2) experience but no adoption, dis-adopter and (3) adopter. An overview of the farmer adopter groups is provided in Table 2.

Table 2. Overview of the three adopter groups and corresponding innovations.

Group	n	Location	Innovation Adopted or Experienced
No experience, no adoption (non-adopter)	14	Germany: n = 3 UK: n = 11	Not applicable
Experience but no adoption (dis-adopter)	9	Germany: n = 5 UK: n = 4	Bacteria, biostimulant, mycorrhiza, plant strengthener, soil additives
Adopter	8	Germany: n = 6 UK: n = 2	Bacteria, biostimulant, ginger quartz, mycorrhiza, plant strengthener, seaweed extract, soil rejuvenator

4.2. Innovation Traits per Group

Figure 2 presents an overview of the percentage of coded statements per innovation trait per group. This illustrates how the innovations traits were identified and discussed to a different degree in each adopter group. Altogether, *relative advantage* received most attention compared to the other innovation traits. The non-adopter group discussed aspects of perceived *complexity* strikingly often, whereas statements referring to *trialability* and *observability* were identified less often than in the other groups. The dis-adopter group discussed *observability* relatively often compared to the other groups.

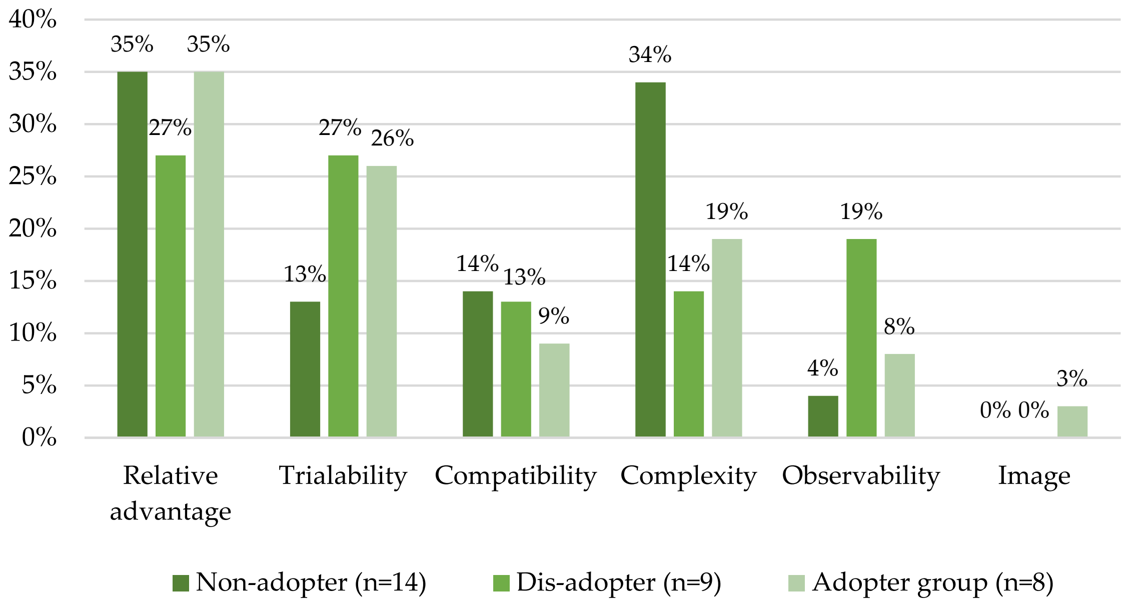

Figure 2. Percentage of coded statements per innovation trait per group.

Detailed results of identified sub-themes of the innovation traits for each group follow.

4.2.1. Non-Adopter Group

The non-adopter group can be defined as the sub-sample with neither experience nor adoption of innovations, such as biostimulants or similar innovations. Yet, their perspective is valuable from two perspectives: first, their perceptions might provide insights into factors which have hindered adoption and/or diffusion to date. Second, despite their current status as non-adopters, they can be potential late adopters, thus belonging to the group of farmers positioned further right (a later stage) on the diffusion curve. Hence, they are also an important target audience to reach in future efforts to diffuse such innovations.

Sample and Context

The non-adopter sample consists of a high share of farmers from the United Kingdom. Table 3 presents an overview of farmers' socio-demographics. As shown in Table 3, the only two female farmers of the sample are both in the non-adopter group. The age and the years of experience of the respondents varies in this sample, between 22 and 65 years, and 2 and 42 years, respectively, with a mean of 44 years and 18 years, respectively.

Table 3. Summary table of socio-demographic statistics of non-adopter sample (n = 14).

Demographic Categories		*n*	Answer Range
Age		14	22–65 years old (mean: 44 years old)
Experience as farmer (in years)		10	2–42 years of experience (mean: 18 years)
Gender:	Male	12	
	Female	2	

An overview of the farm characteristics of the non-adopters is shown in Table 4. It reveals that the sample consists of a strikingly high share of farmers who engage with animal husbandry. This could indicate more diversified farm businesses, and that arable farming plays a minor role in their business. Their farm sizes range from 68 to 800 hectares. Compared to the average of the other adopter groups, the non-adopter group consists, on average, of the smaller farms in our sample, though they are still large compared to the average of the overall population of farmers in their respective country.

Table 4. Summary table of farm statistics of adopter sample (*n* = 14).

Farm Categories	*n*	Mean	Min–Max
Farm size (h in hectare)	13	310 hectares	68–800 hectares
Organic production	1		
Meadowsandforestry	6		
Animal husbandry	10		

Innovation Traits

Table 5 shows the identified sub-themes per innovation trait for the non-adopter group.

Table 5. Deductive and inductive coding of innovation traits by non-adopter sample (*n* = 14).

	Relative Advantage		
	Themes	**Occurrences**	**Percentage**
Direct economic factors	Concerns about limitations in resources needed to adopt	12	13.64%
	Concerns about receiving value (for money)	5	5.68%
	Benefit of application delayed after application	2	2.27%
Other factors	Benefits for the plant: health, vitality, growth	4	4.55%
	Support and/or positive effect on yield	3	3.41%
	Benefits regarding nutrients or nutrient uptake	3	3.41%
	Environmentally friendly	3	3.41%
	Trialability		
	Themes	**Occurrences**	**Percentage**
	Preference/willingness to test product themselves	7	7.96%
	Concerns about resources needed	5	5.68%
	Compatibility		
	Themes	**Occurrences**	**Percentage**
Farm compatibility	Compatibility to other farm practices or measures (need/concern)	3	3.41%
Needs	No other choice left/other choices are decreasing	6	6.82%
	No need identified	4	4.55%
	Complexity		
	Themes	**Occurrences**	**Percentage**
Physical effort	Concerns about how to operate the innovation/technology	7	7.95%
	Need for knowledge	2	2.27%
Mental effort	Interactions and functioning unclear	9	10.23%
	General lack of knowledge/understanding	6	6.82%
	Unclear effects and/or variability of effects	4	4.55%
	Complex soil structure	3	3.41%
	Observability		
	Themes	**Occurrences**	**Percentage**
	Criteria to evaluate effect of technology	4	4.55%

Note: Occurrences are the number of coded statements, and the percentages are based on all occurrences in the non-adopter sample.

Within the trait *relative advantage*, it can be seen that direct economic factors dominate non-adopter farmers' perceived concerns. The non-adopter group has frequently expressed their concern about economic aspects, such as resources required to adopt such innovations, or the (partly insufficient) return they might receive from its application. One farmer in Germany expressed, "[. . .] if it wouldn't incur so many costs, then this would certainly be something where one says: yes, let's have a look". (Farmer ID 41, personal interview, 30 October 2019, quote reference 01, refer to "selected quotes" in the Supplementary Materials). Furthermore, the potentially delayed benefit of using such innovations was expressed. Yet, other aspects of the trait *relative advantage* which do not relate directly to economic factors show that despite the perceived economic challenges the potential advantages for the plant, yield, or regarding nutrients, are acknowledged.

The perceived economic concerns regarding resources needed also played a role with respect to the innovation trait *trialability*. The concern about limitations in required resources was mentioned with regard to trying the innovation. This could potentially be a reason for no experience or, subsequently, no adoption. This need for accessible trials is also indicated with statements referring to farmers' preferences in conducting their own trials. One farmer in Germany indicated his willingness to trial: "I believe I wouldn't have a problem trying something. If you look in a small setting whether it works or not. Because if you really wait until others try it, I think a lot of time can pass [. . .]". (Farmer ID 46, personal interview, 20 November 2019, quote reference 02).

However, despite their lack of experience or adoption, about half of the non-adopter group has expressed the need for such innovations. Several statements expressed this need, such as, "But I think that they [note: biostimulants] will be a part that will become more prevalent in both organic and conventional [farming]. Because especially against the background of the limited available capacities, we already have to think about it". (Farmer ID 51, personal interview, 26 November 2019, quote reference 03). This indicates that the potential of such innovations is acknowledged. Otherwise, the *compatibility* related to their farm conditions was mentioned as a necessary need or concern.

The coded statements related to *complexity* describe a high degree of perceived uncertainty and perceived complexity of the innovation among the non-adopters. This holds for both the mental ability to understand the innovation and also the physical implementation. The required costs to overcome their lack of understanding or perceived physical effort could form an additional barrier to adoption.

The *observability* of the innovation itself, or mainly of its effectiveness, has been described as an important criterion to evaluate the innovation. This was pointed out by a farmer in the UK:

> Whereas, if I put this can of something on, it is going to increase my, you know, I think the cause is not necessarily something that the everyday farmer can see. So it is a bit of an unknown. [. . .] You don't have to take all the samples, send them away to a lab and get them analysed, you know. And I think that is potentially you know, a barrier and a fact that is kind of, it is the unknown. (Farmer ID 18, personal interview, 21 February 2020, quote reference 04)

Lastly, no statements relating to the user's *image* were coded more often than once in the non-adopter group.

4.2.2. Dis-Adopter Group

The sub-sample identified as dis-adopters or experienced farmers can be defined as those farmers that have experience with the innovation, such as conducting trials or temporary implementation on their fields, but discontinued the application. This group may also be called dis-adopter due to the termination of product application. Strictly speaking, this sub-sample would not be allocated on the diffusion curve by Rogers [19]. They cannot be categorized as adopters, but are also different from those without experience. Their perceptions of the innovation are valuable, as they can speak from their unique experience and highlight barriers which may have caused their dis-adoption. Their contribution is valuable to shed light on potential causes of discontinuation of innovation usage after experience.

Sample and Context

The dis-adopter sample consists solely of male farmers in Germany and the UK. Table 6 presents an overview of socio-demographic characteristics of this group. On average, this sub-sample is slightly older (mean 46 years) and slightly more experienced (mean 25 years) compared to the non-adopter group (mean 44 years and 18 years, respectively).

Table 6. Summary table of socio-demographic statistics of the dis-adopter sample (n = 9).

Demographic Categories		*n*	Answer Range
Age		8	27–63 years old (mean: 46 years old)
Experience as farmer (in years)		8	13–39 years of experience (mean: 25 years)
Gender:	Male	9	

On average, these nine farmers manage 490 hectares, with more than half also being involved in animal husbandry or in managing either meadows and/or forestry. See Table 7 for an overview.

Table 7. Summary table of farm statistics of the dis-adopter sample (n = 9).

Farm Categories	*n*	Mean	Min–Max
Farm size (h in hectare)	9	490 hectares	70–1200 hectares
Organic production	2		
Meadowsandforestry	6		
Animal husbandry	5		

Innovation Traits

The identified sub-themes per innovation trait for the dis-adopter sample are presented in Table 8.

Similarly, to the non-adopter sample, it can be seen that within the *relative advantage* concerns related to the innovation's adoption are dominated by direct economic factors in the dis-adopter sample. When comparing the number of occurrences between the two groups, we see that these concerns are frequent in both groups. One farmer described financial return as a reason for dis-adoption:

> But then that fell asleep a bit, because that also cost money, you have to be honest. And I think we also tried something in that direction and tried something out. But somehow we never stuck with it. Because then somehow, it's just a question of money, you simply have to see it that way. It costs money, and if it is not to be recognized then afterwards in the purse, then one leaves again. (Farmer ID 45, personal interview, 19 November 2019, quote reference 05)

However, potential advantages in terms of reduced costs and created value were also identified within the direct economic factors. The majority of advantages created by the innovation were identified in the other factors, through aspects such as benefits created for the plant, the wider environment, and other support mechanisms.

The *trialability* node also revolved around the past experiences and trials that this group had with relevant innovations. Yet, despite their experience as dis-adopters, this group expressed the need for trials as well as for support, and a preference and willingness to conduct further trials. However, concerns about the required resources to conduct trials were also expressed and calls for support were voiced. In this context, one farmer described his experience and time restrictions in conducting trials:

> "We have then also, as I said, employed, laid out rows and so on, such an attempt. Well, now we have not evaluated it to the smallest, we have not done that of course. Because there is time missing to do that". (Farmer ID 45, personal interview, 19 November 2019, quote reference 06)

Table 8. Deductive and inductive coding of innovation traits by the dis-adopter sample (n = 9).

	Themes	Occurrences	Percentage
Relative Advantage			
Direct economic factors	Concerns about limitations in resources needed to adopt	12	8.16%
	Concerns about receiving value (for money)	12	8.16%
	Advantage by cost of product and/or receiving value for money	2	1.36%
Other factors	Benefits for the plant: health, vitality, growth	6	4.08%
	Benefits for the soil	4	2.72%
	Support with extreme (external) conditions	4	2.72%
Trialability			
	Themes	**Occurrences**	**Percentage**
	Trial experience (in the past)	18	12.24%
	Preference/willingness to test product themselves	8	5.44%
	Call or need for trials	6	4.08%
	Concerns about resources needed	6	4.08%
	Call for support with trials	2	1.36%
Compatibility			
	Themes	**Occurrences**	**Percentage**
Farm compatibility	Compatibility to biophysical circumstances on field or farm level (need/concern)	4	2.72%
	Compatibility to equipment or machinery (need/concern)	4	2.72%
Needs	Need to support plant (soil, water, pest resistance, nutrients)	6	4.08%
	No other choice left/other choices are reducing	3	2.04%
	No need	2	1.36%
Complexity			
	Themes	**Occurrences**	**Percentage**
Physical effort	Concerns about how to operate the innovation/technology	12	8.16%
	Need for knowledge	3	2.04%
Mental effort	Interactions and functioning unclear	3	2.04%
	General lack of knowledge/understanding	3	2.04%
Observability			
	Themes	**Occurrences**	**Percentage**
	Observed results from technology: neutral results	13	8.84%
	Observed results from technology: positive results	4	2. 72%
	Concerns/challenge to observe effect	4	2.72%
	Observed results from technology: negative results	3	2.04%
	Criteria to evaluate effect of technology	3	2.04%

Note: Occurrences are the number of coded statements, and the percentages are based on all occurrences in the dis-adopter sample.

Regarding *compatibility*, in the category farm compatibility, the fit to biophysical circumstances on the farm and with farm equipment was equally expressed as a concern and/or need for adoption. In the needs sub-category, the innovation was identified to meet needed support for the plant but also to meet needs of farmers because there is a decline in the use of conventional products due to stricter legislation. However, in two instances, such innovations were specifically mentioned to be unnecessary.

In the subcategory *complexity* the coded statements reflect the general perceived incomprehensibility in terms of physical and mental effort. In terms of occurrences, these statements were coded even more frequently than in the group of the non-adopters. One farmer indicated his lack of understanding also in a lack of clear guidance:

> What are the kind of guidelines, you know, we know don't put fungicides on during the rain and so on and so forth. There are very simple rules about that. But these things [note: soil microbes], how do they work, [. . .] where is the guidance to the usage, that is the stuff that is going to be tricky and that is going to take time. (Farmer ID 17, personal interview, 19 February 2020, quote reference 07)

The content which deals with *observability* captures mainly how farmers describe the results they could observe from innovation usage. These observed results were described in negative, but also positive terms, both in small frequencies. The majority of observed results were referred to in neutral terms, which could mean that those farmers did not observe any results. Therefore, despite a neutral description of the observed effects, farmers' conclusions or evaluations of the innovation might be negative. The importance of observability was also specifically highlighted by some respondents, as the visible observation of effects is used as a criterion to evaluate the innovation. Thus, the lack of observability of effects has been acknowledged as a concern and/or challenge of such innovations. A farmer in the UK described the challenge of visibility in comparison to fungicides:

> Because, you put a fungicide on a plant or an herbicide on a weed. And the weed either dies, half dies, or doesn't die, and you can visually measure it. The disease either stops in its tracks or never appears in the first place. And you can measure it against a control. Whereas, if you put biology on the soil, you can stick a spade in the ground and, I would imagine the bit of soil next to the bit that you have treated would look exactly the same as the bit that you treated for a while. (Farmer ID 17, personal interview, 19 February 2020, quote reference 08)

Finally, also in the dis-adoption group, no statements related to the user's *image* were coded more often than once.

4.2.3. Adopter Group

The adopter group is defined by the fact that they have adopted innovations, such as biostimulants, on their farm at the time of the interview. Given the novelty of the innovation in question, these respondents could potentially be termed so-called early adopters.

Sample and Context

The adopter sample consists, on average, of the oldest farmers from the total sample; the mean age is 51 years old. With a mean of 20 years, they remain in the middle field of farming experience; see Table 9 for an overview.

Table 9. Summary table of socio-demographic statistics of adopter sample (n = 8).

Demographic Categories		*n*	Answer Range
Age		8	39–58 years old (mean: 51 years old)
Experience as farmer (in years)		8	9–31 years of experience (mean: 20 years)
Gender:	Male	8	

In terms of farm size, the adopter sample farms span an average of 396 hectares; see Table 10 for an overview. This group consists of only two farmers (25%) that engage in meadows forestry and one that is involved in animal husbandry.

Table 10. Summary table of farm statistics of adopter sample.

Farm Categories	*n*	Mean	Min–Max
Farm size (h in hectare)	8	396 hectares	100–1400 hectares
Organic production	2		
Meadowsandforestry	2		
Animal husbandry	1		

Innovation Traits

Table 11 presents the adopter group's innovation traits and identified sub-themes (n = 8).

Table 11. Deductive and inductive coding of innovation traits by adopter sample (n = 8).

Relative Advantage			
	Themes	**Occurrences**	**Percentage**
Direct economic factors	Benefits through the reduction of other inputs	13	9.77%
	Concerns about limitations in resources needed to adopt	10	7.52%
	Concerns about receiving value (for money)	8	6.02%
	Advantage by cost of product and/or receiving value for money	2	1.50%
Other factors	Environmentally friendly	4	3.01%
	Support and/or positive effect on yield	3	2.26%
	Benefits for the soil	3	2.26%
	Benefits for the plant: health, vitality, growth	2	1.50%
	Benefits regarding disease and/or pest protection	2	1.50%
Trialability			
	Themes	**Occurrences**	**Percentage**
	Trial experience (in the past)	10	7.52%
	Call or need for trials	8	6.02%
	Concerns about trial evaluation and/or assessment	6	4.51%
	Preference/willingness to test product themselves	6	4.51%
	Concerns about resources needed	4	3.01%
Compatibility			
	Themes	**Occurrences**	**Percentage**
Farm compatibility	Compatibility to biophysical circumstances on field or farm level (need/concern)	5	3.76%
	Compatibility to equipment or machinery (need/concern)	3	2.26%
Needs	Need to support plant (soil, water, pest resistance, nutrients)	2	1.50%
	No other choice left/other choices are reducing	2	1.50%
Complexity			
	Themes	**Occurrences**	**Percentage**
Physical effort	Concerns about how to operate the innovation/technology	5	3.76%
	Product application unclear	2	1.50%
Mental effort	General lack of knowledge/understanding	9	6.77%
	Interactions and functioning unclear	6	4.51%
	Unclear effects and/or variability of effects	3	2.26%
Observability			
	Themes	**Occurrences**	**Percentage**
	Observed results from technology: positive results	4	3.01%
	Observed results from technology: neutral results	3	2.26%
	Observed results from technology: negative results	2	1.50%
	Concerns/challenge to observe effect	2	1.50%
Image			
	Themes	**Occurrences**	**Percentage**
	Positive evaluation of user	2	1.50%
	Negative judgement/association of user	2	1.50%

Note: Occurrences are the number of coded statements, and the percentages are based on all occurrences in the adopter sample.

Within *relative advantage*, the sub-theme direct economic factors consists of more positive factors than was the case in the interviews with the non-adopter and dis-adopter groups. More specifically, benefits through the substitution or reduction of other inputs are mentioned often. However, negative aspects, such as concerns about resources needed for adoption and the potential value they receive, are referred to quite frequently in this group. Other factors in the category relative advantage capture various positive effects for the environment, yield, soil, or plant, which can be potentially achieved when using the innovation. A farmer in Germany also links these advantages to his personal benefits: "So the advantage is actually, if one agrees to work with this product, that the environment agrees with it better than with active substances that I have to choose somehow. Then I have actually already done something for myself". (Farmer ID 47, personal interview, 18 November 2019, quote reference 09).

The node *trialability* consists of statements about their trial experience in the past but also consists of their concerns regarding the conduct of trials. Farmers expressed a need to implement their own trials and also showed willingness to conduct their own trials.

Concerning *compatibility*, several factors related to the fit of the innovation to specific farm conditions were identified. On the one hand, a concern and need to fit to biophysical circumstances was mentioned. A German farmer described his experience as follows:

> But it is also the case that what was known in the first place is that it does not fit on all soils or all locations or forms of farm business, I say it this way now, and that it does not bring the same success everywhere. (Farmer ID 44, personal interview, 29 October 2019, quote reference 10)

On the other hand, compatibility towards the existing equipment or machinery on the farm was mentioned as an important need or concern. General needs were identified in terms of necessary support for the plant itself. The necessity to establish new products was also mentioned as an important development for the future, mainly because conventional options or alternatives are reducing.

Statements coded under *complexity* indicated, despite their experience and adoption, that the innovation is still perceived as rather complex and unclear. Understanding how the innovation works and how its implementation on the field can look seems challenging.

Observability mainly describes the results that farmers of this group have witnessed. The evaluation of these effects appears to be mixed, with slightly more positive than neutral or negative observed results. The challenge to see results was also mentioned in this group.

In the *image* category, both positive and negative evaluations of the user were expressed. One farmer described his view of others experimenting with such innovations and microbes this way: "But there are all these short videos, if you look at it that way. Where they, yes, the freaks I say it that way now, where they report on it and talk about it". (Farmer ID 44, personal interview, 29 October 2019, quote reference 11).

4.3. Communication Channels

Figure 3 illustrates the relationships respondents mentioned in the interviews as information source for innovations, such as soil microbes. Identified stakeholders were grouped into several communication channels (see Table A3 for the absolute numbers of how often each channel was mentioned and the definition of each channel).

The identified communication channels reveal that all groups have relatively high percentage scores on the same channels: "extension service", "farmer community", and "trade and manufacturers". Together these three groups account for more than 70% of channels mentioned to obtain information with respect to innovations (72% adopters, 78% dis-adopters and 77% non-adopters). The biggest gap between the different groups appears to be between the relevance of the channels "private network" and "other contacts". The adopter group clearly engages more with other actors which do not fall in any of the created channels. Whereas, within the "private network" channels, the adopter group engages less than the dis-adopter and non-adopter group.

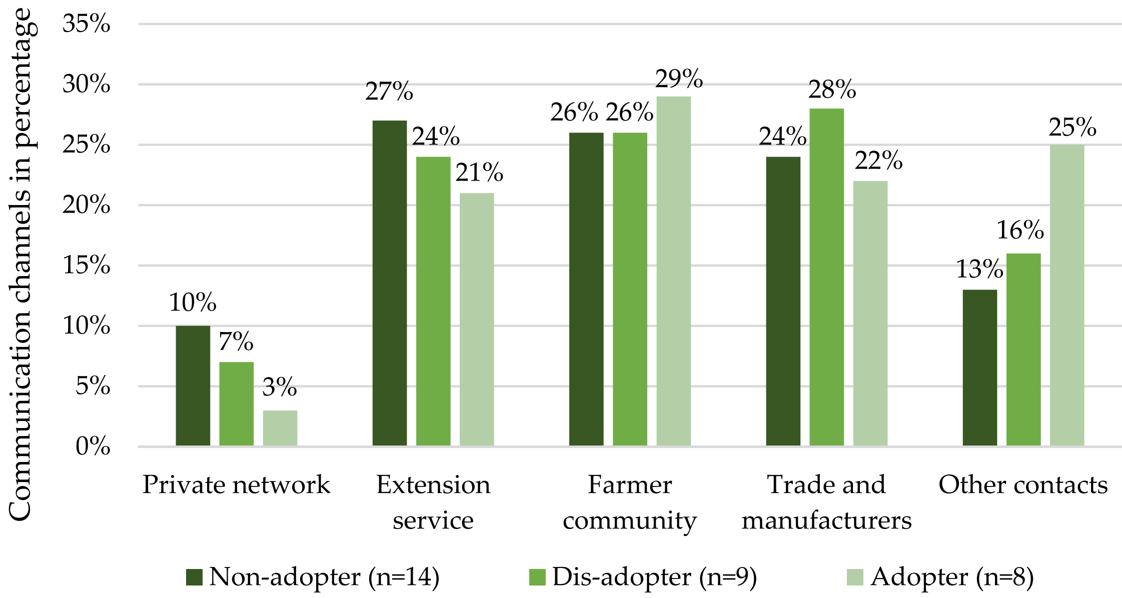

Figure 3. Mentioned communication channels in percentage per group.

5. Discussion

Overall, the comparison between the three adopter groups highlighted that qualitative differences exist in this sample's perceptions. Striking differences between the groups became clear in the different perceptions related to direct economic factors. More positive aspects were mentioned by the adopter group and dis-adopter group than by the non-adopter group. Another potential obstacle identified in all groups is the challenge and need to observe the effects of the innovation. Due to the nature of how these soil microbes work, farmers tend to miss any visible proof or demonstration of their effects. A lack of visible proof could also indicate non-effectiveness of the soil microbes, given that specific conditions (e.g., soil condition or weather) can impact their effectiveness. In an assessment of the traits which influence the adoption of conservation measures, Sattler and Nagel [3] found that observability came second to risks as a category important for adoption by German farmers. All adopter groups perceive the innovation as rather complex to understand and/or apply. Furthermore, Drobek et al. [6] mention a lack of knowledge and understanding regarding the functions and application mechanisms of biostimulants as a reason for low adoption rates. In order to come to a decision, trials conducted by farmers themselves appear to be an important step in the decision process. However, those trials must be accompanied by information on the correct application of the innovation. Furthermore, guidance on how to evaluate the effects (visibly or otherwise) is important. Pannell et al. [47] argued that trialling of innovations will appear more useful to the adopter if high observability can be ensured, as this will allow for more conclusive trials. Concerns were voiced regarding resources and observability, which also applies to trials. This stresses again the need for support to be offered to potential adopters. Despite their different levels of experience, the need for such innovations was acknowledged in all groups. All in all, perceptions that refer to challenges linked to adoption could be identified in all groups, and also for those farmers who already adopted such innovations.

From a theoretical point of view, all concepts were identified in the discussions with farmers. Only the extension of the theoretical framework by the concept *image of the user* was found solely in the adopter group. In a review of diffusion studies, Kapoor et al. [48] show that many studies increasingly incorporate attributes that go beyond the DIT framework. However, in our study the theoretical extension proved relevant only in few instances.

Farmer networks are known to moderate farmers' perceptions of innovations and thus also diffusion patterns. Wood et al. [49] results indicate that innovation processes in agriculture are also determined to a great extent by the farmers' own networking processes.

Diederen et al. [50] researched adoption of agricultural innovations in the Netherlands. The authors found that the farmer network, measured as the number of farmers' memberships in agricultural initiatives, is positively related to adoption. Across the three farmer groups studied here, three stakeholders proved to be especially important in providing innovation-related information to farmers: actors from the extension service, from manufacturers and trade, and the farmer community. Blasch et al. [51] determined that the chances of adoption of precision farming technologies rise with farmers who can observe the technology being used by other farmers. In the context of no-till farming in England, Skaalsveen et al. [52] network analysis showed that no-till networks spread geographically over wide areas, as neighbouring farmers are not necessarily engaging with the same innovative practice. Hence, this supports the conclusion that other farmers, especially from their network, can play an important role in the diffusion of innovations. Blasch et al. [51] also found that for Italian farmers the information of advisors from extension service are the most relevant source of information. Strikingly, in our sample the adopter group also frequently referred to a variety of other stakeholders, which were not explicitly categorized for this study. This indicates that other, more fragmented communication channels appear more frequently among the adopter group.

This study focused on the farmer as the main decision maker in the adoption of soil microbes. Yet, other stakeholders or communication channels can still play an important role in the diffusion of soil microbes and biostimulants. An additional fifteen interviews were conducted with a variety of stakeholders from the potato industry in Germany and the UK. Results of these interviews are reported in the Supplementary Materials and generally reinforce our findings based on the farmer sample. However, future research could focus more on perspectives of key up- and downstream stakeholders who are important for the diffusion of innovations.

6. Conclusions

During the start of data collection in Germany, many German farmers engaged in protests to show their disagreement with political decisions and perceived external pressures potentially threatening their businesses [53]. These farmers were voicing their concerns over the future viability of agriculture as we know it today. These concerns point towards a need to integrate the farm perspective in the development of technological and institutional solutions or innovations for sustainable agriculture. Our study provides first insights regarding drivers of perceptions of one such innovation—the uptake of beneficial soil microbes.

However, some caveats of this study are worth noting. Given the qualitative nature of our study and our, accordingly, relatively small sample size consisting of potato farmers from two regions, no conclusions can be drawn towards the overall farmer population in the UK nor in Germany. Instead, our focus was on the depth and breadth of opinions, which exhibited a remarkable degree of nuance and diversity. Another limitation lies in the process of data generation and analysis. The process of data generation and analysis emerged from the same research process. However, because the theoretical framework of the content analysis was not yet defined at the time of data collection, we can assume that the interviews were still conducted without a bias in this direction. Another common bias in personal interviews is a possible social desirability bias. The participants' answers may be biased towards more acceptable and desirable answers. Knowing that the interviewer conducts research on soil microbes may have contributed towards a less critical conversation about biostimulants or soil microbes with the farmers. On the other hand, the fact that at the time of interviews, farmers in Germany were protesting against environmental and farm animal regulation, could have made farmers more critical with respect to the topic.

Considering these limitations, this research provides explorative insights into perceptions of beneficial soil microbes from the (potential) adopters' perspectives, which were previously hardly discussed in an academic context. Our research has shown that farmers in Germany and the UK still perceive soil microbes and biostimulants as challenging products for adoption, despite different levels of experience with such innovations. Simultaneously, positive aspects were acknowledged by all adopter groups, specifically with slightly more positive perceptions in the groups with more experience. The concepts of the innovation traits by Rogers [19], *relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability*, helped capture perceived challenges or advantages. As potential barriers for diffusion, the traits *complexity* and *observability* were often perceived negatively or as a challenge. Within perceived *relative advantages* and *compatibility*, aspects which can contribute positively but also aspects which can challenge a diffusion of the soil microbes were mentioned. Future communication efforts of such innovations could benefit from taking up the identified perceived challenges and concerns. Possible actors who might engage in such communication strategies are those from extension services and manufacturers themselves. Additionally, many farmers refer to other farmers from their network; thus, communication between farmers can serve as an important channel for exchange and diffusion.

Supplementary Materials: The following supporting information can be downloaded at: https://osf.io/xdn3z/ (accessed on 9 December 2021, last edits on 9 May 2022).

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The interviews presented in this article are not publicly available to protect the privacy of research participants.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Definition of innovation characteristics identified by Rogers [19] and additional sources.

Innovation Characteristic	Definition	References
Relative advantage *	Relative advantage is the degree to which an innovation is perceived to be better than the idea it supersedes. The degree of relative advantage is often expressed as economic profitability, social prestige, or other benefits.	Rogers, 1995 [19], p. 212
Cost	The cost of an innovation.	Tornatzky and Klein, 1982 [21], p. 36
Profitability	Profitability is the degree to which an innovation may create profit through adoption, this may not be applicable to all innovations.	Tornatzky and Klein, 1982 [21], p. 37

Table A1. *Cont.*

Innovation Characteristic	Definition	References
Compatibility *	Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. An innovation that is more compatible is less uncertain to the potential adopter and fits more closely with the individual's life situation.	Rogers, 1995 [19], p. 224
Complexity *	Complexity is the degree to which an innovation is perceived as relatively difficult to understand and use. Any new idea may be classified on the complexity–simplicity continuum.	Rogers, 1995 [19], p. 242
Trialability *	Trialability is the degree to which an innovation may be experimented with on a limited basis. New ideas that can be tried on an instalment plan are generally adopted more rapidly than innovations that are not divisible.	Rogers, 1995 [19], p. 243
Divisibility	Divisibility is the "extent to which an innovation can be tried on a small scale prior to adoption", which is closely related to trialability. This trait describes to what degree the innovation can be tried only in separate parts.	Tornatzky and Klein [21], 1982, p. 37
Observability *	Observability is the degree to which the results of an innovation are visible to others. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to observe or to describe to others.	Rogers, 1995 [19], p. 244
Communicability	Communicability is the degree to which an innovation can be communicated to others, which is closely related to observability.	Tornatzky and Klein, 1982 [21], p. 36
Image *	Image is the degree to which using an innovation is perceived to enhance one's image or status in one's social system.	Moore and Benbasat, 1996 [23], p. 173
Social approval	Social approval is the degree to which status can by gained due to adoption.	Tornatzky and Klein, 1982 [21], p. 37
Voluntariness of use	The degree to which use of the innovation is perceived as being voluntary, or of free will.	Moore and Benbasat, 1991 [22], p. 203

* Innovation traits included in theoretical framework and codebook (deductive codes).

Table A2. Codebook.

Code	*Description*	*Literature/References*	*Coding Rule*
Relative advantage	Relative advantage is the degree to which innovation is perceived as being better than the idea it supersedes. The degree of relative advantage is often expressed as economic profitability or other benefits. The nature of the innovation determines what specific type of relative advantage is important to adopters.	Rogers, 1995 [19], p. 212	Any statements related to social advantage or prestige code under 'image'.
Direct economic factors	Code perceptions about relative economic advantages and disadvantages associated with the innovation.		
Non-economic factors	Code perceptions about relative non-economic advantages and disadvantages associated with the innovation.		

Table A2. *Cont.*

Code	*Description*	*Literature/References*	*Coding Rule*
Compatibility	Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. A more compatible idea is less uncertain to the potential adopter and fits more closely with the individual's life situation. Such compatibility helps the individual give meaning to the new idea to be regarded as familiar.	Rogers, 1995 [19], p. 224	Only code in subcodes.
Sociocultural values *	Perceived compatibility or incompatibility with sociocultural values and beliefs.	Rogers, 1995 [19], p. 224	
Previous ideas	Perceived compatibility or incompatibility with previously introduced ideas/previously adopted ideas.	Rogers, 1995 [19], p. 224	
Needs	Perceived compatibility or incompatibility with (the farmers') needs for the innovation.	Rogers, 1995 [19], p. 224	
Farm compatibility	Perceived compatibility or incompatibility with farm-specific conditions, infrastructure, and environment. This includes, for example, available equipment or machinery.		
Other (compatibility) *	Other aspects of perceived compatibility.		
Complexity	Code perception of the innovation's complexity. Complexity is the degree to which an innovation is perceived as relatively difficult to understand and use. Some innovations are clear in their meaning to potential adopters whereas others are not.	Rogers, 1995 [19], p. 242	Only code in subcodes.
Mental effort	Code perceived complexity with regard to mental effort or difficulty.	Davis, 1985 [54], p. 26	
Physical effort	Code perceived complexity with regard to physical effort or difficulty.	Davis, 1985 [54], p. 26	
Other (complexity) *	Other perceptions regarding complexity.		
Trialability	Code perception of the innovation's trialability. Trialability is the degree to which an innovation may be experimented with on a limited basis. New ideas that can be tried on the instalment plan are generally adopted more rapidly than innovations that are not divisible. Some innovations are more difficult to divide for trial than are others. The personal trying-out of an innovation is a way to give meaning to an innovation, to find out how it works under one's own conditions.	Rogers, 1995 [19], p. 243	Code observability in trials or observability due to trials in "observability" code
Observability	Code perception of the innovation's observability. Observability is the degree to which the results of an innovation are visible to the farmer (user), others and potential adopters. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to observe or to describe to others.	Rogers, 1995 [19], p. 244	
Image	Code perceptions of image changes. Image is the degree to which using an innovation is perceived to enhance one's image or status in one's social system. Social approval is the degree to which one's status can be increased due to the innovation.	Moore and Benbasat, 1996 [26], p. 137; Tornatzky and Klein, 1982 [24], p. 37	

Table A2. *Cont.*

Code	*Description*	*Literature/References*	*Coding Rule*
Image (positive)	Positive enhancement of one's image due to the innovation.		
Image (negative)	Negative enhancement of one's image due to the innovation.		
Adoption	Statements describing the participant's actual and/or previous direct usage or direct experience with innovations (behavioural response). This includes statements about current and past usage and experiences.		Only code in subcodes. Code yes or no statements if generic answers, code innovation itself if innovation-specific statements are given. Only applicable for farmer sample.
Yes (general)	Statements describing previous usage or experience with innovations. Can be undefined time commitment/implementation phase or long-term integration/adoption.		
Yes (past)	Statements describing previous usage or experience with innovations but discontinued the usage (so no long-term implementation), that is, trials only.		
No (use)	Statements describing no usage nor experience with innovations.		
Communication channels	Statements or simple terms and phrases that mention the stakeholder relevant for sources of information or diffusion, contact points which provide information/innovation or similar. This refers to general contact points (not innovation-specific). Subcodes: Extension service (private), extension service (public), manufacturers, agricultural trade, farmers (neighbourhood), farmers (network), family, friends, neighbours (non-farmer), academia/researcher, other stakeholder		Only code in sub-codes. Ordinal subcodes. Only mark the term/name for the stakeholder.

* Codes excluded due to low occurrence/low number of coded statements.

Table A3. Communication channels.

Channels	**Explanation**	**Non-Adopter**		**Dis-Adopter**		**Adopter**	
		n	%	*n*	%	*n*	%
Private network	Family, friends, neighbours	12	10	6	7	3	3
Extension service	Private and public extension services	31	27	21	24	23	21
Farmer community	Farmer neighbours, networks, associations	30	26	23	26	32	29
Manufacturers and trade	Manufacturers and trade	28	24	25	28	24	22
Other contacts	i.e., academia, staff, organic organizations	15	13	14	16	28	25
Total		116	100	89	100	110	100

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