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ORIGINAL ARTICLE

Communicating about plant breeding and genome editing in plants: Assessment of European stakeholders, sources, channels and content

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Abstract

Genome editing helps to develop plant varieties that address future agricultural challenges such as climate change adaptation, resource efficiency and sustainable productivity. Nevertheless, associated aspects relating, besides others, to the regulation of genome editing, intellectual property rights and potential environmental and health aspects lead to fierce discussions within the European Union. In these discussions, values and moral aspects play a decisive role. To support and set the stage for an open-minded dialogue, the communication behaviour and needs of specific stakeholder groups has been analysed by means of two online surveys. The surveys considered sources and channels used for information sourcing and dissemination, conveyed content and relevant target audiences. In addition, the degree of trust of stakeholders in different information sources was assessed. Stakeholders included representatives from academia, civil society organisations (including environmental and consumer organisations), journalists, the farming community, the seed and plant breeding sector and policymakers across Europe. Our analysis suggests that, in general, a high level of trust is associated with representatives from academia, and that safety-related aspects, transparency and sustainability are considered very important topics across the different stakeholder groups. In addition, social media seem to play a subordinate role for inter-stakeholder communication but is of higher relevance for reaching out to the public.

KEYWORDS

communication, controversial, controversy, discourse, genome editing, new plant breeding techniques

1 | INTRODUCTION

Genome editing techniques enable the targeted modification of DNA sequences in organisms and contribute to the breeders' toolbox when breeding new plant varieties to address future challenges, for example caused by climate change or contributing to more sustainable agricultural crop production and achieving the political goals as set by the EU Green Deal (EC, 2019a).

As a result of the European Court of Justice's (ECJ) ruling from 2018 (case C-528/16), plants produced by genome editing fall under the scope of the rules and regulations for genetically modified organisms (GMO) in the EU (EC, 2003b, 2003a, 2001, 2013, 2015, 2018). Plants resulting from genome editing thus have to undergo a stringent risk assessment process (Reference for a preliminary ruling—Deliberate release of genetically modified organisms into the environment—Mutagenesis—Directive 2001/18/EC—Articles 2 and 3—Annexes I A and I B, Grand Chamber [The Court], 2018). In contrast, plants resulting from classical mutagenesis breeding are exempted from this regulation due to the history of safe use of those breeding processes.

Within the agricultural sector, the success of technology adoption largely depends on the farmer's human capital, on local (agronomic and climatic) conditions and the acceptance by consumers, regulators and non-governmental organisations (NGOs). Thus, a technology cannot be viewed in isolation but needs to be contextualised by considering the socio-cultural settings surrounding the respective debate (Chavas & Nauges, 2020; Lassoued et al., 2018). In the case of genome editing, the initial framing of the GMO debate and the judgement of the ECJ set the stage for a risk-focused discourse (Bechtold, 2018). This is also highlighted by the fact that the so-called precautionary principle is frequently used within the public debate to question the safety of genome-edited plants from the outset (Lassoued et al., 2019). The precautionary principle was originally set into place to assist decision making under scientific uncertainty and has been anchored as a core principle in the European environmental legislation. This precautionary approach states that *'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'* (General Assembly, 1992). Based on a content analysis of position papers and press releases of German discourse stakeholders, Siebert et al. (2021) describe two major strategic frames used by proponents and opponents of regulation. The latter warn that the use of genome editing in agriculture would pose an inestimable risk, due to 'unknown uncertainties', and the former highlight the view that there is a lack of public trust in scientific results. Further complexity is added as involved stakeholders have conflicting views on the future of agriculture, and contradictory-scientific evidence might be used to support one or the other argument (Lassoued et al., 2019). Alongside scientific information, emotions, values and moral aspects play a decisive role within the public debate surrounding genome editing as well (Bechtold, 2018).

For citizens, it is impossible to evaluate the credibility of available scientific information, and so the level of trust they do assign to an information source might instead be an important determinant to accept their recommendation (Hunt & Frewer, 2001). The question of trust directly links back to shared values within the individual stakeholder group(s). To be considered trustworthy depends on experiences in three dimensions, that is the attribution of (1) skills (e.g. experience and expertise), (2) integrity (e.g. honesty and truthfulness), and (3) good intentions (e.g. focusing on public welfare and protecting the environment; Jonge et al., 2008). Emotions and values have a critical role in building trust, especially in cases where no first-hand evaluation of scientific statements is possible (Khodyakov, 2007). A survey commissioned by the European Food Safety Authority (EFSA) revealed that European citizens are most likely to trust scientists (82%) and consumer organisations (79%) for information on food-related risks, followed by farmers (69%), national authorities (60%), EU institutions (58%), NGOs (56%) and journalists (50%). To a smaller extent, citizens consider supermarkets and restaurants (43%) or food industries (36%) as trustful sources, while only 19% trust celebrities, bloggers and influencers (European Food Safety Authority, 2019).

To allow for an informed public discourse about genome editing and to prevent that biased information is provided by the involved stakeholders, a recent report of the European Commission (EC) highlights the need for mechanisms that ensure the validity of the provided information (European Commission DG Research and Innovation, 2021). In addition, the European Group on Ethics (EGE) proposed to broaden the risk-focused debate and consider costs and benefits as well. EGE recommends including a comparative impact assessment by considering the scenario to continue to use current practices compared with the scenario of any potential future use of crops resulting from genome editing. Considerations may include a potential impact on the environment, the need to combat climate change and to ensure food security. Furthermore, it is suggested that regulations should be proportional to the potential risks, a view that is highly contested by some NGOs (Panella et al., 2015) by highlighting the precautionary approach and requesting a full risk assessment for genome-edited plants. In contrast, the innovation principle, as promoted by the EC (2019b), argues that 'EU policy and legislation should be developed, implemented and assessed in view of encouraging innovations that help realise the EU's environmental, social and

economic objectives, and to anticipate and harness future technological advances'.

To facilitate an open discourse as promoted by the EGE, understanding the underlying communication behaviour of participating and interested stakeholders is of utmost importance.

The EU-funded H2020 project CropBooster-P includes the development of a communication strategy that aims at achieving an open-minded discussion on plant genome editing that should guide communication efforts of future EU-funded research projects in this context. To start this endeavour, we identified and selected major stakeholder groups involved in the public debate, including academia, civil society organisations (covering consumer and environmental organisations), policymakers, the farming community, the seed and breeding sector and journalists. The communication behaviour of included stakeholders was analysed by means of two online surveys, assessing:

1. The perception of the public debate surrounding plant genome editing across major European regions.
2. The level of trust different stakeholders put in major information sources.
3. Information seeking and communication behaviour of stakeholders involved in the public debate, including

   a. Considered information sources,
   b. The identification of major topics that should be addressed when communicating about plant genome editing,
   c. Supposed target audiences and associated communication channels.

Here, we present the results gathered by the qualitative and quantitative analyses of the collected inputs and discuss their potential implication for developing a broader communication strategy. In line with the observation that scientific interest in communication strategies about food-related risks and benefits is fairly recent to the authors' knowledge, no empirical data on European stakeholders' information and communication behaviour on plant genome editing are available so far (Frewer et al., 2016). Our results thus provide an essential source of information for anyone interested or involved in communication about plant genome editing in particular or new plant breeding techniques in general.

2 | METHODS

Two online surveys were conducted to collect data on the communication activities and experiences of European stakeholders involved in the public discourse. The focus of the survey was on the typical communication and information behaviour of respondents regardless of coronavirus pandemic conditions. Due to the diversity and specific challenges of reaching the targeted stakeholder groups, two surveys were conducted. The goal was to maximise the response rate through the targeted use of professional networks of the research partners in the recruitment process. A description of the surveys is presented in Table 1.

2.1 | Survey A

The stakeholder panel enrolled in survey A was obtained from a contact database created through online searches and was mainly limited to organisations that have a German and/or English website. The database consisted of 408 references: environmental organisations (98 references), scientific academies and networks in plant (breeding) research (90 references), consumer organisations (65 references), journalists' associations and (individual) journalists (155 references) from 16 European countries and the EU level.[1]

The invitation to survey A with an anonymous survey link was distributed by email and via contact forms on the target groups' websites. The network representatives were asked to disseminate the invitation to the survey in their network. In addition, a snowball sampling was applied based on referrals from initially sampled participants to other potential respondents from the stakeholder groups of interest. Finally, the CropBooster-P project webpage and Twitter were used to publish the survey invitation on the internet and social media.

Participants were asked to respond on behalf of themselves or on behalf of the organisation they work for. The survey included, among other things, questions on respondents' perception of the public discourse about new plant breeding technologies in the countries they work, on their information behaviour and communication activities and experiences regarding new plant breeding techniques like genome editing. The survey was initially developed in German and translated into eight languages (English, French, Spanish, Italian, Greek, Polish, Romanian, and Bulgarian) by a professional translation agency. Native-speaking research partners in the project consortium double-checked the translated versions.

After data evaluation, 109 responses of organisations and individuals could be used for analysis. In this process, only complete survey responses were retained for analysis. Most of the respondents were academics and worked in Western European countries.

TABLE 1 Description of surveys[a]

	Study A		Study B	
Survey period	June–September 2021		March–May 2021	
Survey method	Online survey		Online survey	
Survey duration (median)	13.5 min		17.5 min	
Description of the samples	***N***	**%**	***N***	**%**
Stakeholder group (SHG)	**109**	**100**	**166**	**100**
Academia	50	46	-	-
Civil Society Organisation (CSO)[b]	22	20	-	-
Journalists	27	25	-	-
Seed and Breeding sector	4	4	100	60
Farmer and Farmer organisation	-	-	55	33
Policymaker	2	2	11	7
Others	4	4	-	-
Region[c]	**109**	**100**	**166**	**100**
Western European Countries (WEC)	61	56	106	64
Northern European Countries (NEC)	10	9	10	6
Eastern European Countries (EEC)	14	13	26	16
Southern European Countries (SEC)	13	12	22	13
EU	6	6	0	0
Not named	5	5	2	1
Sex	**86**	**100**	**88**	**100**
Female	35	41	21	24
Male	49	57	66	75
No response	2	2	1	1
Age	**86**	**100**	**88**	**100**
25–34	10	12	15	17
35–44	17	20	22	25
45–54	21	24	16	18
55–64	26	30	28	32
≥65	12	14	7	8

[a] The questionnaires are available by the authors upon request.

[b]Civil Society organisations include consumer organisations and environmental organisations.

[c]WEC (Austria, Belgium, France, Germany, Netherlands, Switzerland); NEC (Denmark, Finland, Latvia, Norway, Sweden, United Kingdom); EEC (Bulgaria, Poland, Romania); SEC (Greece, Italy, Spain).

2.2 | Survey B

The target groups of survey B were three different stakeholder groups: farmers/farmer organisations, breeders/seed and plant breeding organisations and policymakers. Based on the number of breeding companies, national associations in the seed and plant breeding sector and farmer organisations and aiming to obtain a representative sample for different European regions, a selection of 10 countries[2] was prioritised.

Targeted invitations to participate in survey B were sent to individuals and organisations within each stakeholder group via email. Furthermore, the survey links had been widely shared on the social media platforms Twitter and LinkedIn and through direct contact with external organisations of relevance.

Participants were asked to respond on behalf of themselves or on behalf of the organisation they work for. The survey included questions to retrieve information about the knowledge, experience, limitations and needs related to communication. Part of the survey included questions about genome editing. To enable broad participation, and to reduce English language only bias, the survey was translated into the official national language of each of the prioritised countries.

After data evaluation, 166 stakeholder responses could be used for analysis: 55 from farmers/farmer organisations, 100 from breeders/seed and plant breeding

organisations, and 11 from policymakers. More than half of the responses in the policymaker group were from participants who work at the European Parliament or European Commission.

Both surveys cannot be quantified in relation to the representation of the stakeholder groups surveyed. The results presented in the next section must be interpreted against this background.

The data from both surveys were integrated and analysed using SPSS[3] version 26. Some questions were not identically operationalised in the two surveys. Such differences and their potential effects on interpreting the results are documented in the section 'Discussion'. The evaluations aim to compare the communication and information behaviour of the European stakeholder groups involved in the debate. The stakeholder groups were considered as a whole. Thus, the analyses focussed on the commonalities and differences between and among these six stakeholder groups. In addition to the comparative analysis between stakeholder groups, the data were also analysed for four European regions.[4] These European regions are based on the geographical regions of Europe used by the Statistics Division of the United Nations: Eastern Europe, Northern Europe, Southern Europe and Western Europe. Descriptive and inductive statistical methods are used. Due to the non-random survey methodology and the small and unequal sizes of the sub-samples, the assumptions for parametric test procedures (ANOVA) were not met. Therefore, the non-parametric Kruskal–Wallis test, which does not compare the mean differences but the differences in the rank sums between the sub-groups, was applied to detect significant differences. Due to the lower statistical power, small differences are less likely to be indicated as significant.

3 | RESULTS

First, we present results unique to Study A on the perception of the public discourse in different European regions related to plant genome editing for the respondents from academia, civil society organisations and journalists. All other results regarding trust, information seeking and communication activities are based on the combined data set from study A and B, which includes the farming community, the seed and plant breeding sector and policymakers to the stakeholder comparative analyses. In addition to the stakeholder-specific analysis, data are also analysed for significant differences between the four designated European regions, that is Western European countries (WEC) including Austria, Belgium, France, Germany, Netherlands, Switzerland, Northern European countries (NEC) including Denmark, Finland, Latvia, Norway, Sweden, United Kingdom, Eastern European countries (EEC) including Bulgaria, Poland, Romania and Southern European countries (SEC) including Greece, Italy, Spain.

3.1 | Perception of the public discourse about genome editing and the degree of trust

Stakeholders were asked to assess the discourse they perceive in the country where they work based on various characteristics. The use of a bipolar scale enabled the representation of regional perception profiles (Figure 1).

Nineteen per cent of the respondents did not perceive any public discourse about genome editing in their country of employment. About half of the respondents from Eastern European countries report that there is no public discourse on the topic in their home countries (see Annex: Table A1). Provided that a discourse was perceived, the respondents characterised the public discussions as polarised, emotional and deadlocked. In addition, not all stakeholders seem to be equally involved in the discourse. Except for the respondents from Eastern European countries, the discourse is perceived as socially relevant. The perception of a polarised discourse is particularly pronounced among respondents from Western European countries.

How stakeholders and the public perceive the course and facets of the public discourses and involved stakeholders is influenced by the trust placed in the discourse participants, in their communicative goals and arguments (Hunt & Frewer, 2001). Figure 2 shows the level of trust different stakeholders assigned to the individual stakeholders involved in the debate about food production and genome editing in plants. Since the number of respondents in some groups is low, the data should be interpreted as tendencies. Regarding food production and genome editing in plants, academia and education providers indicated the highest level of trust among stakeholder respondents. Most respondents trust them fully or a little. In contrast, on average, environmental organisations and the media are trusted the least. However, trust in environmental organisations is very variable among the stakeholders surveyed. For example, the trust of civil society organisations and policymakers in environmental organisations is positive, in contrast to the other four stakeholder groups.

Figure 2 also shows that the civil society organisations surveyed do not trust seed and plant breeding companies at all. The trust of all other stakeholders in breeding companies is significantly higher and varies between 'neutral' and 'trust a little'. Even though the level of trust addressed in Study A focused on communication about genome editing in plants and Study B focused on communication

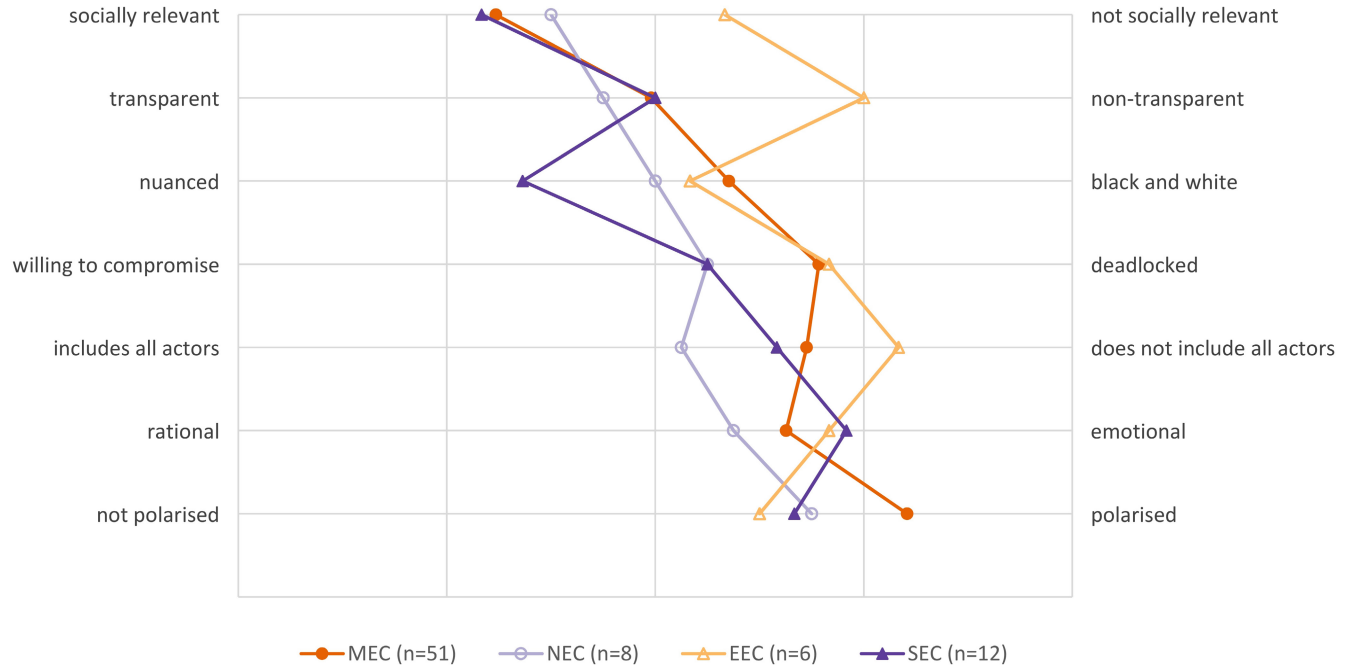

FIGURE 1 Perception of the public discourse about plant genome editing according to respondents[a] home region (means).
[a] Respondents = Academia, Civil Society Organisations (include consumer organisations and environmental organisations), Journalists. EEC, Eastern European countries; NEC, Northern European countries; SEC, Southern European countries; WEC, Western European countries.

about food production, the gathered results are discussed together as both topics are highly interconnected.

Significant differences in trust in national authorities between European regions are evident from the data. In the Eastern European countries, the level of trust of the surveyed stakeholders in the national authorities is significantly lower than in Western and Northern Europe (see Annex: Table A2).

3.2 | Information-seeking behaviour regarding genome editing in plants

To develop effective communication materials for individuals and organisations interested in genome editing, gaining insights into the information channels and sources primarily used by the involved stakeholder groups can help. Figure 3 illustrates the preferences of each surveyed stakeholder group regarding nine potential information sources. 'Education providers and academia' is the most frequently mentioned source of all stakeholder groups. This stakeholder group is the only one that all respondents indicated as an important source. Furthermore, the results show that academia primarily uses information from other academia, which suggests a limitation of this stakeholder group to diversify and appreciate information from a larger community. Except in the case of civil society organisations, consumer organisations are mentioned least frequently as a relevant information source.

While significantly more of the seed and plant breeding and farmer representatives prefer national authorities as a source of information, EFSA, as a European authority, is significantly more important for civil society organisations and journalists.

A comparative assessment of the different information sources across European regions revealed that national authorities are significantly more often preferred for information sourcing in Northern European countries (see Annex: Table A3). This is in line with the results on the attribution of trust in national authorities in these European regions (see Annex: Table A1). Journalists are significantly more often preferred as a source of information in Western European countries.

Figure 4 presents the responses of each surveyed stakeholder group on the use of 10 potential channels for gathering information. Conferences, workshops and seminars are important information channels for many respondents from academia, civil society organisations and the seed and breeding sector. Scientific publications are especially important for academia, journalists and the seed and breeding sector. Contributions in technical journals are significantly more important for farmers and the seed and breeding organisations than for the other stakeholder groups. More than 50% of civil society organisations, seed and breeding organisations and policymakers use websites when searching for information. Social media is also considered less important as information channel than the 'classical' channels (radio, TV and the

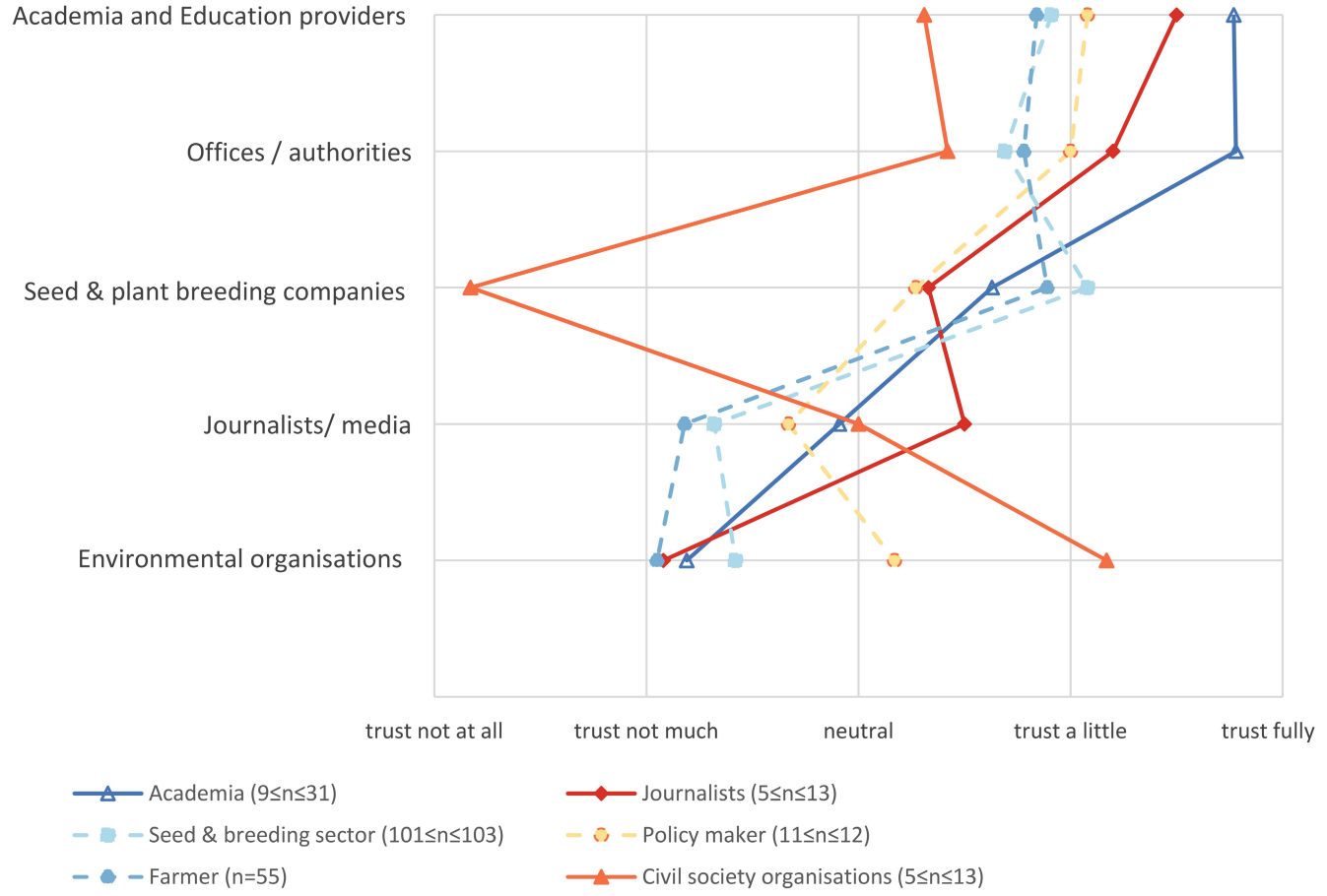

FIGURE 2 Level of trust survey stakeholders put into the different stakeholders regarding information about food production and plant genome editing (weighted means[a]). Study A: How much do you trust the following groups when they communicate about genome editing in plants in your country? (−2 = not at all, −1 = not much, 0 = neutral, 1 = a little, 2 = fully). Study B: Please indicate your degree of trust in the following organisations regarding information and communication about food production in Europe. (−2 = completely distrust; −1 = distrust, 0 = neither trust nor distrust, 1 = trust, 2 = completely trust). [a] The weighting factor is calculated as the quotient of the target and actual distribution of the stakeholder groups. The target distribution corresponds to an equal distribution of the stakeholder groups in the sample. ($x \leq n \leq y$) represents the range of received responses from each surveyed stakeholder group for the assessed stakeholders. Reading example: In the survey, five journalists rated their trust in offices and 13 journalists rated their trust in environmental organisations. The means per SHG refer to these different case numbers.

printed press). Twitter appears to be most frequently used by about 20% of the respondents from academia, civil society organisations and journalists. Blogs and podcasts seem important for journalists and the farming community, whereas Facebook only plays a minor role, limited to the farming community and civil society organisations.

3.3 | Communication behaviour and views on communication about genome editing in plants

The topics to communicate about, the target audience and the communication channels used to convey the content to the audience are of central importance for any communication strategy. Therefore, the following results will focus on these elements.

To assess the communication topics, we collated a list of individual issues based on desk research and explorative interviews that could be addressed by the stakeholders when communicating and reporting about plant genome editing. Short explanations were integrated with the online surveys to ensure each respondent understood/interpreted each term as similarly as possible. Figure 5 shows how the stakeholder groups considered the importance of particular topics in their communication activities. The individual topics are ordered according to the weighted mean of the total sample, starting with the most important topic.

Safety-related aspects, transparency and sustainability are considered important topics for communication by all stakeholders. While safety and sustainability are considered equally important, transparency is significantly more important for civil society organisations than the other

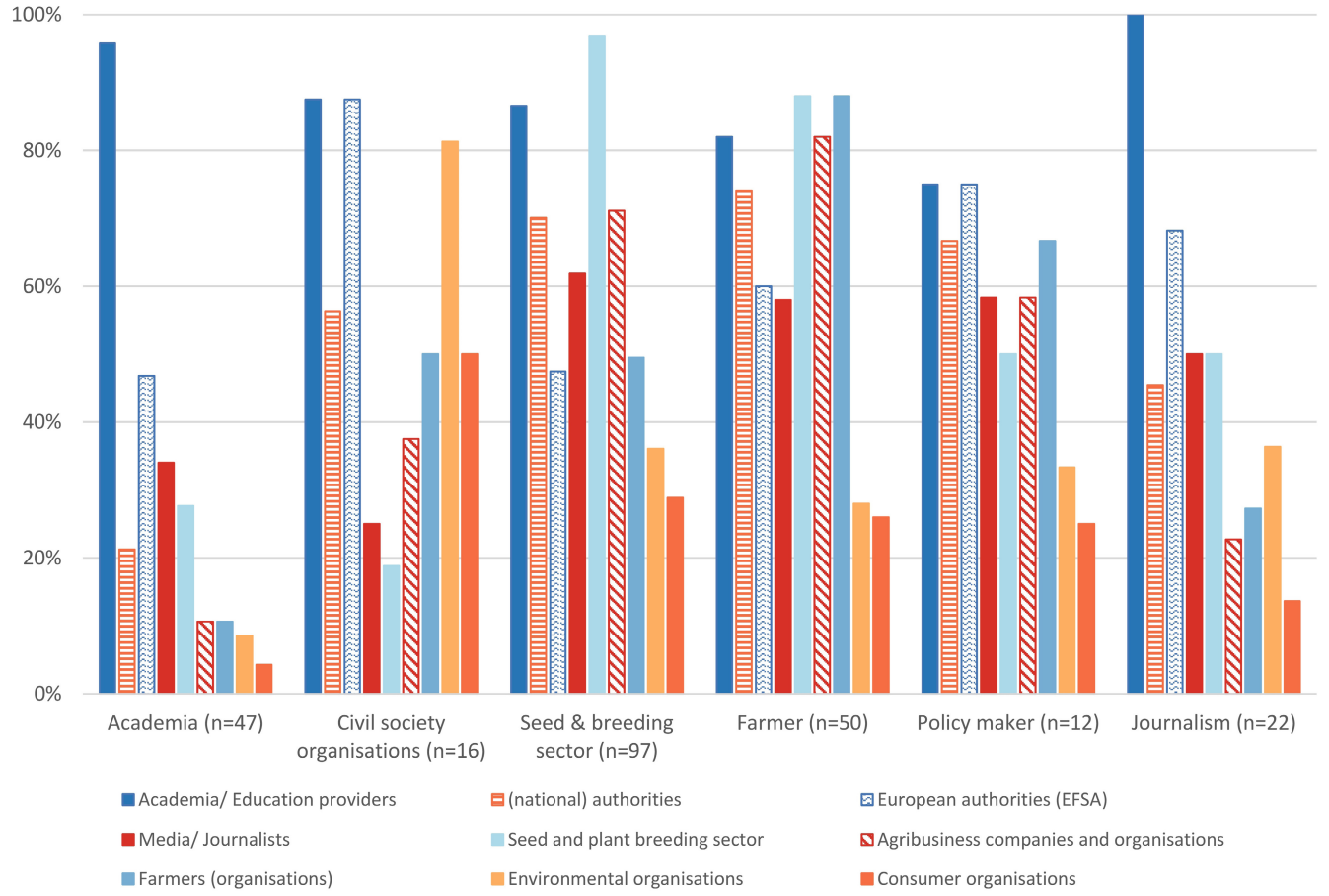

FIGURE 3 Preferred sources of European stakeholders regarding genome editing in plants—% of respondents. Study A: From which groups do you use information on genome editing in plants? (multiple answers possible). Study B: How frequently do you inform yourself by the following stakeholders on gene editing in plants? (5-point scale from 1 = never; 2 = seldom; 3 = sometimes; 4 = often; 5 = almost always) transformed into a binary variable (0 = never and seldom; 1 = sometimes, often, almost always).

stakeholder groups. The topics of regulation and labelling are also rated significantly more important by civil society organisations than the other stakeholder groups. For the surveyed journalists and representatives of academia, patenting (as intellectual property protection for genome editing applications in plants) is significantly less important in communication and reporting than for other stakeholder groups.

Participants of Study A were asked to briefly describe how they address the issue of sustainability in their communication about genome editing in plants in case they rated this topic as very or extremely important. Those answers (n = 49 out of 80) were analysed to determine whether participants addressed genome editing in a supportive, rejective or neutral way and what they associate with sustainability. Analysis of the responses resulted in 91 topic-related statements, categorised in nine categories. Especially the 'use of chemicals (e.g. pesticides)' (n = 21) and the 'use of natural resources (e.g. water and land)' (n = 15) were mentioned, followed by 'plant adaption to biotic and abiotic stresses' (n = 11), 'food security' (n = 10), genome editing in relation to a 'sustainable agriculture and food system' (n = 8), 'long term effects on the whole system' (n = 7), 'political aspects (e.g. Sustainable development goals, regulation)' (n = 4) and the 'reference to organic agriculture' (n = 4). Eleven statements were assigned to the category 'Others'. A total of 30 participants addressed genome editing in plants in a supportive manner, three participants used rejective arguments, and 16 participants addressed the issue neutrally. Mainly respondents from academia and journalists addressed genome editing in plants in a supportive manner (n(A) = 15; n(J) = 10), whereas respondents from environmental organisations used rejective (n(EO) = 2) or neutral arguments (n(EO) = 2) in equal parts, but no supportive ones. Respondents from consumer organisations addressed the topic neutrally (n = 5).

There are significant differences in the evaluation of the communication content between the European regions: Southern and Eastern European stakeholders rated the nutritional quality of food significantly higher. On the other hand, sustainability is significantly less important

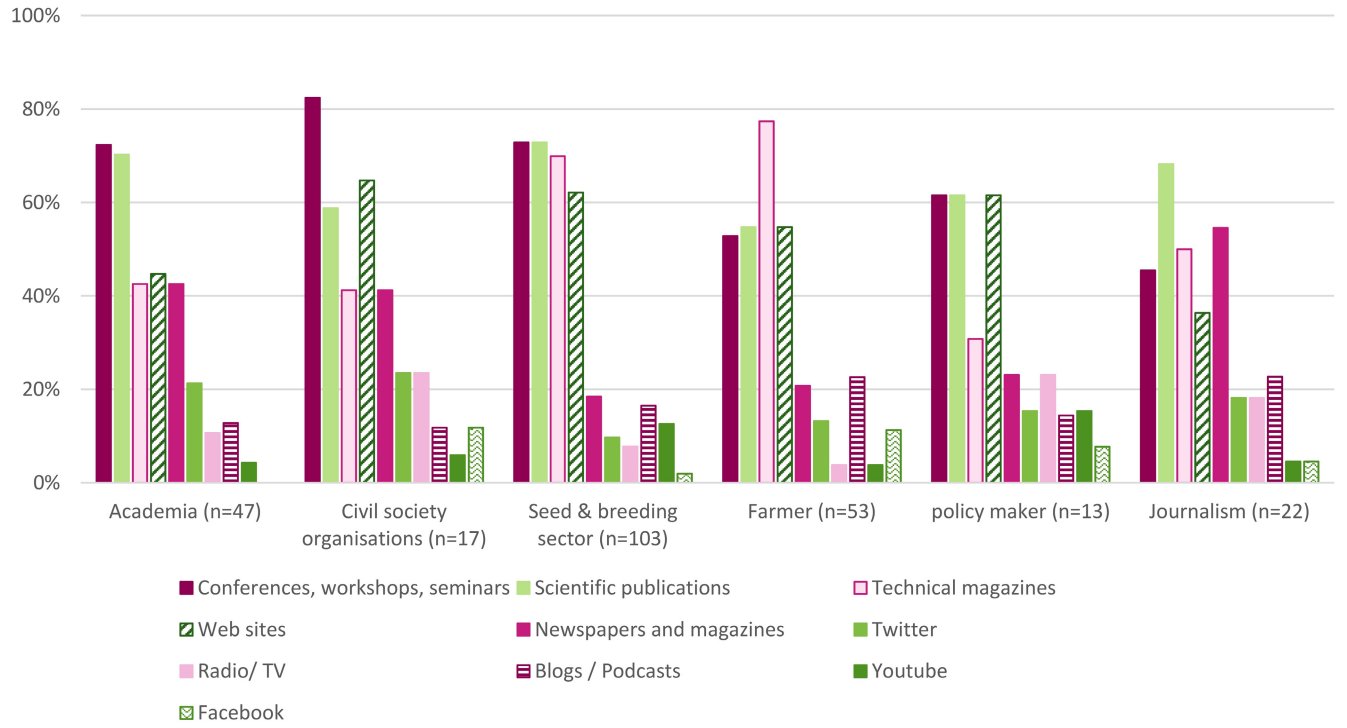

FIGURE 4 Information channels of European stakeholders regarding genome editing in plants—% of respondents. Study A: Where do you inform yourself about genome editing in plants? (multiple answers possible). Study B: Which of the following channels do you use to learn about gene editing in plants? (max. 5).

for stakeholder groups from Eastern European countries when communicating about genome editing and food production (see Annex: Table A4).

A specification of target audiences is the next element of communication that was addressed in the surveys. The surveyed stakeholder groups partly communicate to different target audiences about genome editing (Figure 6). Policymakers are an important target audience for civil society organisations as well as for the seed and plant breeding sector and the farming community. Academia[5] primarily addresses the public, however, communication with farmers or agribusinesses is limited, which resembles the challenge of translating fundamental scientific discoveries and findings from lab to concrete applications, also referred to as the so-called 'Valley of death'. Figure 6 also shows that agribusinesses and the seed and plant breeding sector are not target audiences for civil society organisations when communicating about genome editing. In addition, no significant regional differences were detected in the data concerning target audiences because of low sample sizes. Nevertheless, it seems that Eastern European stakeholders are considerably less likely to indicate policymakers as a target audience than stakeholders from other parts of Europe (see Annex: Table A5).

What channels do the stakeholder groups use to communicate about genome editing? Figure 7 shows that across all stakeholder groups, direct contacts/interactions during conferences, discussion events, seminars and workshops are the most important channels for communicating about genome editing and related issues. Websites are also frequently used as communication vehicles across all stakeholder groups, except for policy-level respondents. Beyond that, however, the different communication channels are used quite differently. It was shown that respondents from civil society organisations use 'classical' media, such as print media and radio/TV, more often than average. Technical magazines are an important communication channel for respondents from the seed and breeding sector, farming community and civil society organisations. Scientific journals are the only channel policymakers do not use for communication purposes, while the other stakeholders do so with varying frequency. The use of social media is also quite different. While the surveyed representatives of academia prefer Twitter as a communication channel, Facebook is more important for the other stakeholder groups.

With regard to a regionally differentiated use of communication channels, there are significant indications in the data for newspapers/magazines and social media: newspapers/magazines are used significantly more often by Northern European stakeholders for communication purposes. Northern Europeans also stand out in terms of social media use, as they frequently use Facebook and Twitter. A comparison of Facebook and Twitter use(−rs)

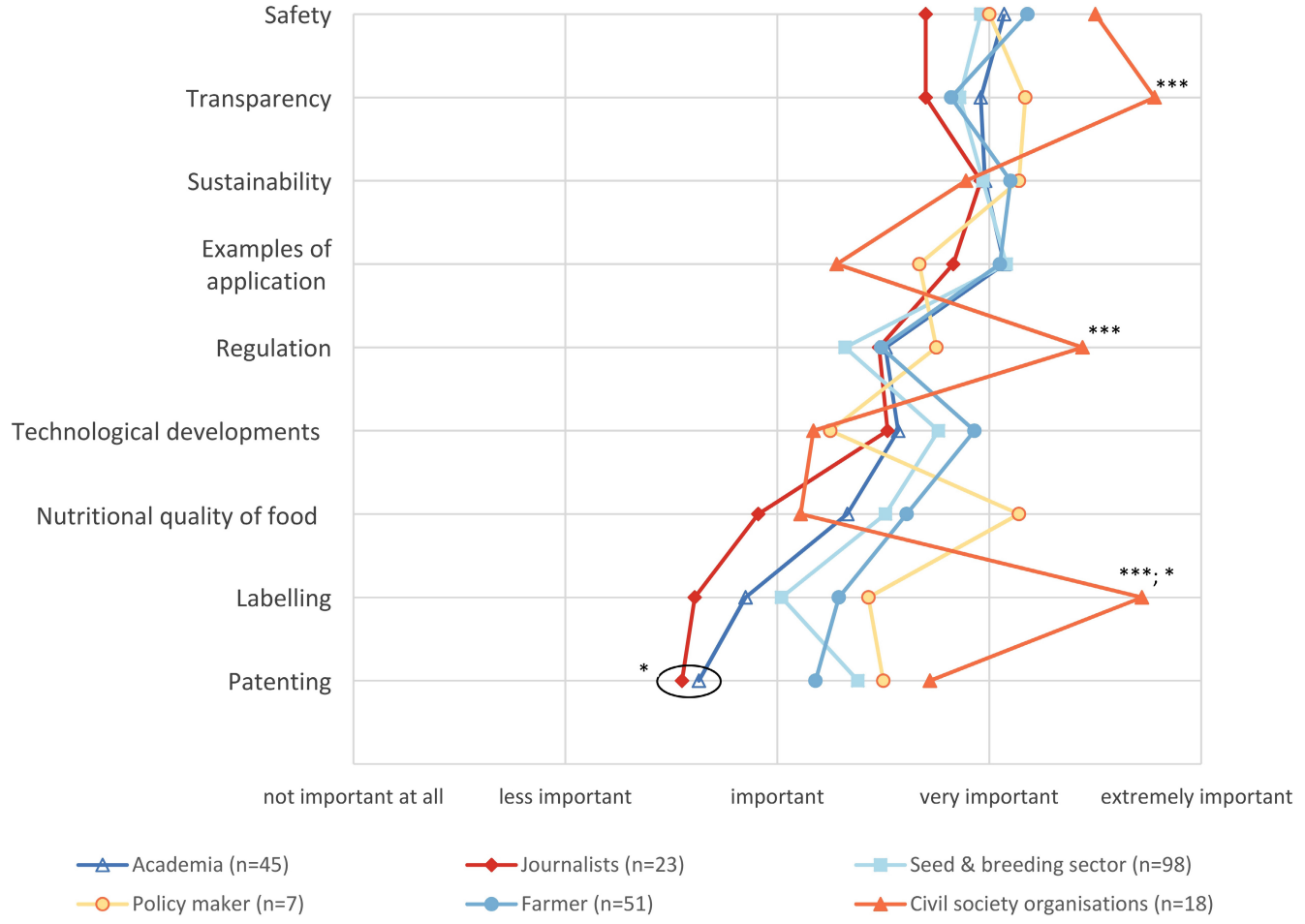

FIGURE 5 Importance of communication topics related to genome editing in plants—Means. *, **, *** indicate significant differences at $p \leq 0.05, 0.01, 0.001$ according to Kruskal–Wallis H-test. Study A: How important are the following types of content in communication about genome editing in plants now and in the future? Study B: Which of the following aspects do you regard as important for communicating about gene editing in plants in the future? (Technological developments, examples, safety, legal aspects, intellectual property, transparency)? How do you rate the importance of addressing the following aspects through communication efforts? (Sustainability, nutritional value, labelling).

in the European regions shows the following conspicuous features: Facebook is significantly more important than Twitter for Eastern European stakeholders. In Western Europe, Facebook is significantly less important. (see Annex: Table A6).

4 | DISCUSSION AND CONCLUSIONS

In Europe, there is controversy about new plant breeding techniques and associated aspects relating, besides others, to the regulation of genome editing, intellectual property rights and potential environmental and health aspects to address future agricultural challenges such as climate change adaptation. To set the stage for an open-minded dialogue between different stakeholder groups, communication activities with regard to sources, channels used for information gathering and dissemination, conveyed content and relevant target audiences were analysed by means of two online surveys across Europe.

4.1 | Perception of the public discourse about genome editing and the degree of trust

More than three quarters of the respondents were aware of a public discourse about plant genome editing in their country of employment. Interestingly, this seems to be less the case for respondents from Eastern European countries. The respondents characterised the public

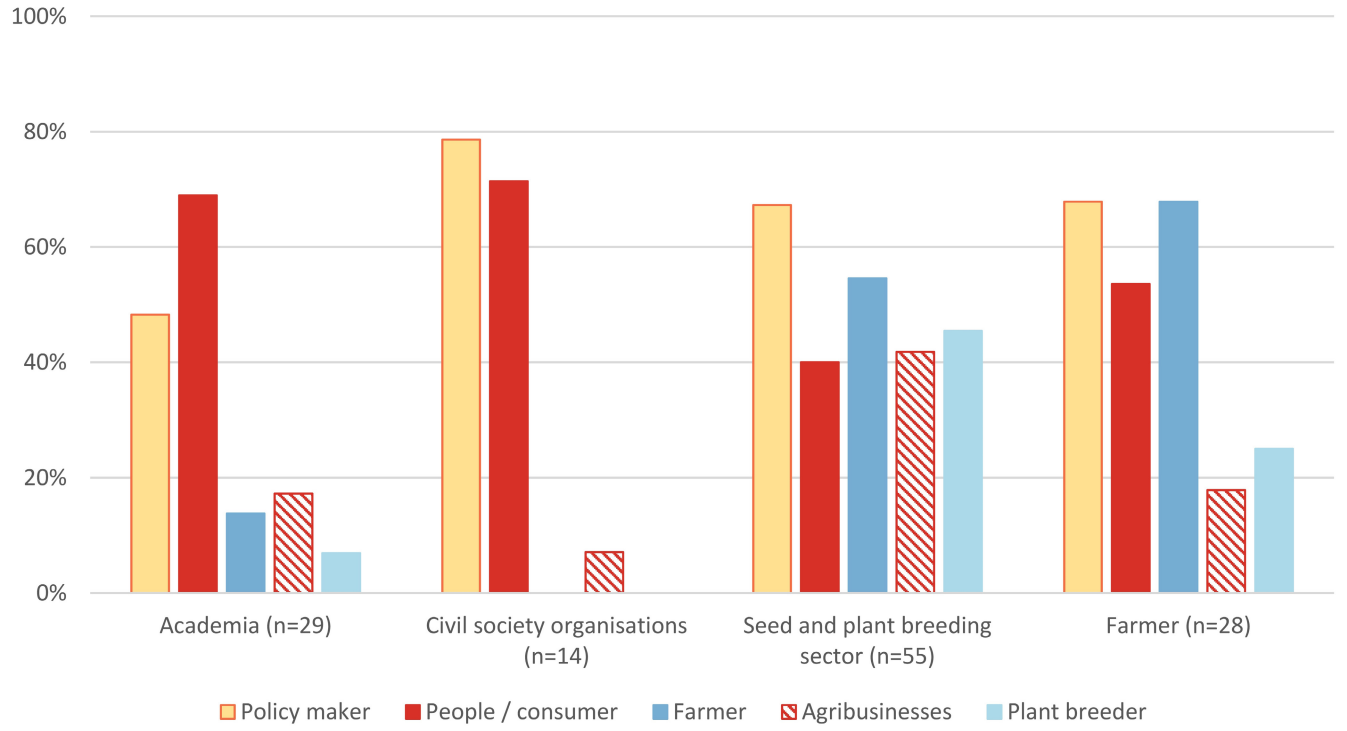

FIGURE 6 Target groups of communication about genome editing in plants (In addition to the target groups presented in this Figure, journalists and media are an important target group of academia and civil society organisations, as an additional result of study A. Data are available by the authors upon request.)—% of respondents. Study A: Who are your main target groups when communicating genome editing in plants? (max. 3) Study B: Which are your main target groups to communicate with about gene editing on plants? (max. 3).

discussions in their home countries as polarised, emotional and deadlocked. Furthermore, the perception of a polarised discourse appears to be particularly pronounced among respondents from Western European countries.

Discourse perceptions are linked to the degree of trust that respondents put in different stakeholder groups. Education providers and academics are most trusted regarding information on food production and plant genome editing, except in the case of respondents from environmental and consumer organisations. In contrast, environmental organisations and the media are the least trusted. In addition, the survey results revealed that environmental and consumer organisations distrust seed and plant breeding companies, while they trust environmental organisations. In Eastern European countries, surveyed stakeholder groups indicated a lower level of trust in national authorities, compared with stakeholders of other European regions.

The survey results highlight that education providers are attributed to a high level of trust from most stakeholder groups and can therefore play a fundamental role in disseminating information and bringing different stakeholder groups together. This is especially relevant in the context of communication about more sensitive topics such as genome editing. Care should be taken that a responsible science communication should not focus on a single solution but should highlight potential synergistic effects within the plant breeding process (Mehta & Vanderschuren, 2021).

4.2 | Relevant communication channels for information gathering

Conferences, workshops and seminars are important information channels for respondents from academia, environmental and consumer organisations and the seed and plant breeding sector. Moreover, scientific publications are especially important for academics, journalists and plant breeders. Interestingly, information gathering through technical magazines is more important for farmers and plant breeders compared with other stakeholder groups. Websites are the only online source consistently used by all stakeholder groups when searching for information. In this respect, up-to-date web presence remains an important communication basis.

Interestingly, social media is considered less important as information channel. Twitter appears to be most frequently used by approximately 20% of the respondents from academia, environmental and consumer organisations and media. Blogs and podcasts seem important

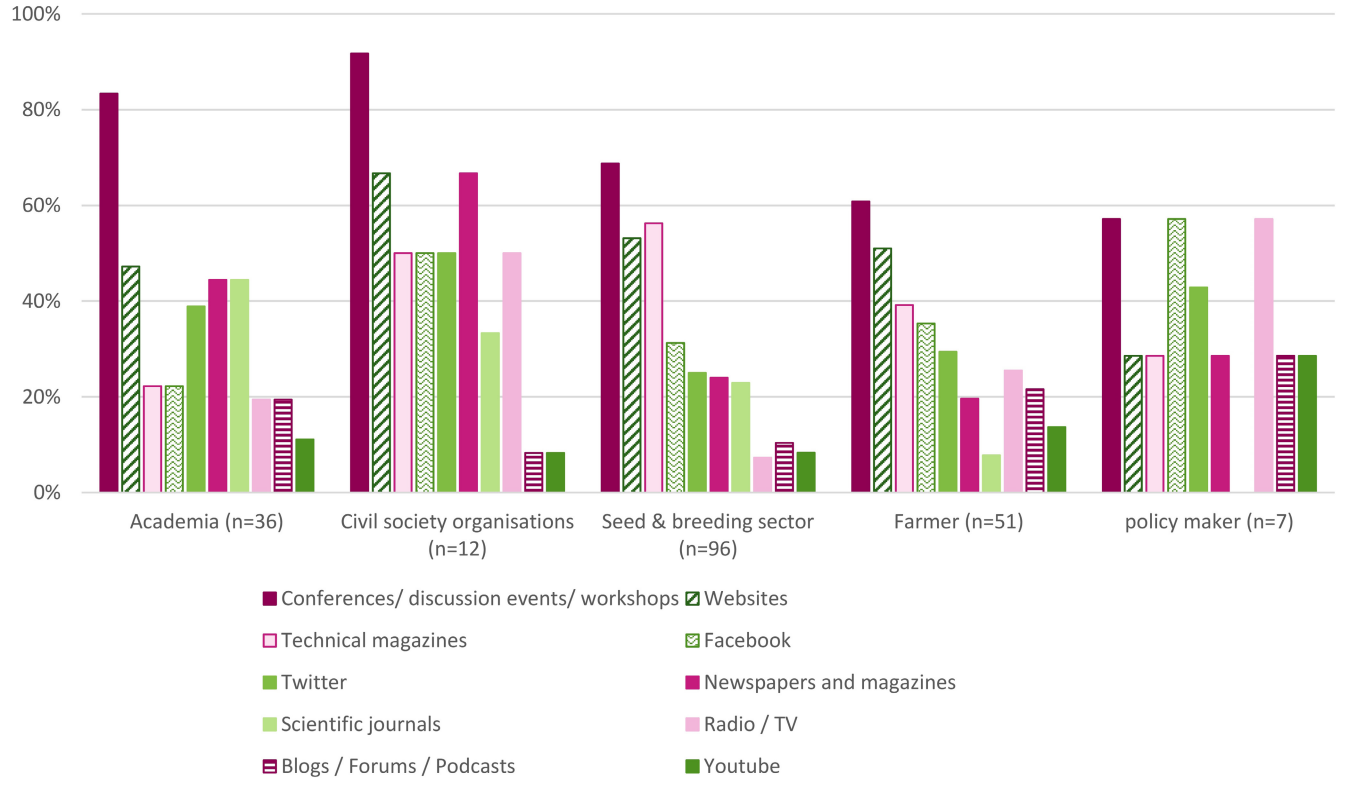

FIGURE 7 Preferred channels of communication—% of respondents. Study A: Which formats and channels do you use to reach your target group(s)? Study B: Which of the following channels do you use to communicate with your main target groups about (plant research/crop improvement/crop production?

for journalists and farmers, whereas the relevance of Facebook for information gathering is rather limited to farmers and environmental and consumer organisations.

4.3 | Relevant communication channels for communication purposes

Survey results revealed that across all stakeholder groups, direct contact during conferences, discussion events, seminars and workshops are the most important activities for communication about plant genome editing. In addition, websites were also frequently indicated as important communication vehicles across all stakeholder groups, except for policy-level respondents. Beyond that, however, other communication channels are used quite differently. Respondents from environmental and consumer organisations prefer to use newspapers and magazines and radio or television more often than average. Technical magazines are an important communication channel for respondents from the seed and plant breeding sector, farming community and environmental and consumer organisations.

Social media platforms are less relevant and used differently depending on both stakeholder group and European region. It appears that policymakers prefer to communicate via many different social media platforms, which suggests that social media is considered valuable to improve visibility and increase engagement with target audiences. Academics prefer Twitter as a communication channel, while Facebook is more important for other stakeholder groups. Respondents from Northern European countries frequently use both Facebook and Twitter, while Facebook is preferred in Eastern European countries and Twitter in Western European countries. These region-specific trends suggest that communication strategies tailored to the target audience and region are essential to use social media as effective communication channel for primarily raising awareness about genome editing.

4.4 | Relevant stakeholder groups for information gathering

Education providers and academia were indicated as important sources by the respondents. Given that this stakeholder group is trusted by most stakeholder groups suggests that the degree of trust is an important determinant in the selection of sources for communication purposes or vice versa. Besides academia, governmental organisations are important sources as well. However, the seed and plant breeding, as well as farmer respondents, prefer national authorities as a source of information,

while EFSA, the European Food Safety Authority, is more important for environmental and consumer organisations and media. Interestingly, preference for national authorities seems stronger in Northern European countries compared with Eastern European countries. The lower trust in national authorities in Eastern European countries could be the reason why this stakeholder group is not a preferred source of information.

4.5 | Relevant stakeholders as target audiences for communication purposes

Policymakers are an important target audience for environmental and consumer organisations as well as for the seed and plant breeding sector and the farming community. According to the survey results, education providers and academia primarily focus communication activities on a wide audience and are less likely to address policymakers and the farming community in communications about plant genome editing. This corresponds with the observation that academia prefers scientific publications and conferences for communication purposes. As academia is most trusted by all stakeholder groups, it is worth considering whether academia should address plant genome editing more actively with policymakers and farmers. There is also potential in terms of active communication with farmers: Ferrari (2021) could demonstrate that Italian rice farmers' positive attitudes towards genome-edited plants. This is a good starting point for academia and farmers to engage and communicate with each other. In addition, an intensification of direct academic-farmer communication is recommended to overcome the 'Valley of death'.

4.6 | Preferred topics on communication about genome editing in plants

Sustainability, safety-related aspects and transparency are considered the most important topics for communication about plant genome editing by all stakeholders. However, sustainability is less important for respondents from Eastern European countries. The topic of sustainability related to genome editing in plants is primarily addressed by respondents in a supportive manner, for example reduced dependency on plant protection products. These respondents are mainly from academia and the media, while environmental organisations prefer to use rejective or neutral argumentation in communication about sustainability in the context of plant genome editing. Participants who reject genome editing as possibility to increase sustainability in agriculture mostly argue that expanding organic farming is more effective than focusing on one method to change the system sustainably in the long term. Neutral argumentation mainly covers value-free argumentation regarding long-term effects on the whole system and food security, as well as open questions which point out a lack of research in potential fields of usage. Interestingly, respondents from consumer organisations address the topic impartially, presumably because no genome-edited products have reached the European market yet. Focussing on sustainability in communication activities might increase the opportunity to agree on shared values among different stakeholders and could provide a starting point to broaden the debate on applications of plant genome editing. Two recently conducted citizen juries[1] with consumer experts and societal stakeholders concluded that the acceptance of new plant breeding techniques by society could be increased when its application serves goals with a societal dimension such as environmental sustainability, resilience and quality (Nair et al., 2022, Stetkiewicz et al., 2022).

A safety-related debate on genome editing seems to be primarily demanded by environmental and consumer organisations, which corresponds with the findings of Siebert et al. (2021) that risk-related statements are most frequently used by plant genome editing critical stakeholders in Germany. However, communication about safety-related aspects does not necessarily imply that this is a consequence of a risk-focused approach. In the case of farmers for example, safety is the most important topic presumably because they are, to a large extent, responsible for the food safety and health requirements related to crops that are the basis for food production.

While safety and sustainability are considered equally important among stakeholder groups, transparency is more important for environmental and consumer organisations than other stakeholder groups. In addition, the topic of regulation and labelling is also rated more important by these organisations. Bechtold (2018) argues that a wise labelling strategy could open up the possibility of focusing the discussion on shared values (e.g. protection of the environment, human health) which could be achieved with the help of genome editing. Labelling and the transparency it creates is also the basis for ensuring consumers' freedom of choice. In addition, the topic of transparency is worthwhile exploring, as for instance transparent research processes are characterised by openness and dialogue. In this regard, Bouchaut and Asveld (2020) discussed the safe-by-design approach, which allows for the structured involvement of different stakeholders in the research process, leading to the anticipation of potential risks and addressing potential concerns different stakeholder groups have.

Policymakers seem to communicate about a more diverse set of topics, which might resonate more with different elements of society. This is in line with recommendations put forward by the EGE, to broaden the risk-focused debate

and consider costs and benefits, including the impact of continuing to use current agricultural practices, in any potential future use of genome-edited crops. Addressing a broader set of topics around plant genome editing in future communication activities should be considered as a good strategy for other stakeholder groups to better connect with society.

4.7 | Important considerations about the reported results

The aim of the study was to provide an overview of the information and communication structures and needs of different stakeholder groups across Europe. For this reason, no valid statements can be made about potential differences with regard to the communication and information behaviour within the groups (intragroup diversity). However, it can be assumed that personal preferences of the individual communicators in particular impacts their communication and information behaviour. Cultural differences in communication behaviour were attempted to be approached through the regional grouping in the analysis. But again, differences between individual countries could not be validly captured. For this purpose, it would be necessary to conduct country-specific case studies.

Additionally, because of limitations in sample size and composition, both surveys cannot be quantified in relation to the representation of the surveyed stakeholder groups; hence, the reported results must be interpreted against this background. In particular, the results on civil society organisations and policymakers can only be taken as first indications. Nevertheless, no empirical data on European stakeholders' information and communication behaviour on plant genome editing has been available so far. Therefore, our results provide an important source of information for anyone interested or involved in communication activities about genome editing in plants.

Major recommendations suggested by the authors to be considered when communicating about plant genome editing are depicted in Box 1.

BOX 1 Authors' recommendations to be considered when communicating about plant genome editing

Recommendation I: Include common societal goals (e.g. sustainability aspects) in the narratives about plant genome editing in future communication activities to gain attention of a broad range of stakeholder groups.

Recommendation II: Engage with education providers and academics to bring different stakeholder groups together and to facilitate an open-minded dialogue about genome editing in plants.

Recommendation III: Consider also reaching out to the target audience via professional magazines and facilitating informational activities via in-person activities.

Recommendation IV: Frequently update websites with the latest information to provide interested stakeholders with relevant in-depth information about crop-related topics, genome editing and potential synergistic effects when breeding new plant varieties.

Recommendation V: Use social media platforms to raise awareness about plant genome editing and to guide target audiences to relevant websites with more background information.

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CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the annex of this article or are available from the corresponding author upon reasonable request.

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ENDNOTES

[1] Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Romania, Spain, Sweden, Switzerland, United Kingdom.

[2] Denmark, France, Germany, Greece, Italy, Netherlands, Poland, Romania, Spain, and United Kingdom.

[3] IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.

[4] The responses of the six EU-level stakeholders and the five respondents who did not specify a country could not be included in these comparative analyses.

[5] In addition to the target groups presented in Figure 6, academia address journalists and researchers/scientific organisations in the communication activities regarding GE in plants, as an additional result of study A (Data are available by the authors upon request).

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ANNEX A

TABLE A1 Perception of a public discourse about genome editing in plants in respondent's country of employment—(% of respondents)

	Total ($n = 109$)	WEC ($n = 61$)	NEC ($n = 10$)	EEC ($n = 14$)	SEC ($n = 13$)	EU ($n = 6$)
No perception	19	15	20	50	8	0
Perception	81	85	80	50	92	100

Data source: Study A.

TABLE A2 Trust in the different stakeholders regarding information about food production and genome editing in the European regions (weighted means)

		Academia and education providers	Consumer organisations	Environmental organisation	Journalists/ media	Farmers and farmer organisations	Agribusiness and industry associations	Seed and plant breeding companies	National authorities*	European authorities
WEC	*N*	123	90	115	105	92	94	113	89	90
	Mean	1.03	−0.19	−0.49	−0.34	0.45	0.13	0.44	0.79	0.97
NEC	*N*	19	12	16	11	9	10	9	9	7
	Mean	1.08	−0.05	−0.30	−0.49	1.13	−0.18	0.47	1.28	1.08
EEC	*N*	23	19	23	24	19	19	19	19	20
	Mean	0.85	−0.28	−0.80	−0.70	0.60	0.31	0.89	0.22	0.62
SEC	*N*	34	24	30	28	26	26	27	24	27
	Mean	0.96	0.23	0.03	−0.37	0.62	0.08	0.52	0.61	1.34

Note: 5-point Likert scale: −2 = completely distrust; −1 = distrust, 0 = neither trust nor distrust, 1 = trust, 2 = completely trust.

Data source: Merged data from Study A and B.

*, **, *** indicate significant differences at $p \leq 0.05, 0.01, 0.001$ according to Kruskal–Wallis *H*-test.

TABLE A3 Preferred stakeholder groups for information sourcing in the European regions (per cent)

	Academia	Consumer organisations	Environmental organisations	Media/ journalists**	Farmers (organisations)	Agribusiness companies and organisations*	Seed and plant breeding sector	(national) authorities**	European authorities (EFSA)
WEC ($n = 149$)	80.9	18.2	34.4	54.6	49.8	45.7	54.5	52.6	58.4
NEC ($n = 20$)	100.0	34.0	41.1	15.3	32.0	79.7	65.6	80.3	69.7
EEC ($n = 31$)	90.6	19.1	21.9	43.1	46.9	41.4	51.2	26.6	43.2
SEC ($n = 36$)	80.1	24.3	33.4	45.0	43.1	38.7	46.8	54.1	71.5

Data source: Merged data from Study A and B.

*, **, *** indicate significant differences at $p \leq 0.05, 0.01, 0.001$ according to Chi^2-Test.

TABLE A4 Importance of communication topics regarding genome editing in plants in the European regions (weighted means)

		Safety**	Labelling	Transparency	Patenting	Examples of application	Technological developments	Regulation*	Sustainability*	Nutritional quality of food***
WEC	*N*	147	131	147	147	147	147	147	131	131
	Mean	3.89	3.18	3.88	3.19	3.85	3.52	3.52	3.93	3.22
NEC	*N*	20	20	20	20	19	20	20	20	20
	Mean	4.36	3.46	4.35	2.87	3.95	3.52	4.02	4.36	3.09
EEC	*N*	32	32	32	30	32	32	31	31	32
	Mean	4.34	3.30	4.16	3.33	4.00	3.72	3.82	3.73	3.94
SEC	*N*	39	31	39	39	39	39	39	31	31
	Mean	4.32	3.65	4.23	3.23	3.78	3.51	3.87	4.20	3.75

Note: 5-point Likert scale: 1 = not important at all; 2 = less important, 3 = important, 4 = very important, 5 = extremely important.

Data source: Merged data from Study A and B.

*, **, *** indicate significant differences at $p \leq 0.05, 0.01, 0.001$ according to Kruskal–Wallis *H*-test.

TABLE A5 Target groups (TG) of communication about genome editing in plants in the European regions (per cent)

	TG: People	TG: Farmer	TG: Agribusiness companies	TG: Seed and breeding companies	TG: Policy maker
WEC ($n = 73$)	57.8	36.4	14.2	14.7	70.1
NEC ($n = 18$)	67.0	23.6	16.4	9.5	59.3
EEC ($n = 15$)	39.9	39.3	19.6	17.0	33.5
SEC ($n = 17$)	57.8	13.0	47.8	18.3	52.5

Data source: Merged data from Study A and B.

TABLE A6 Channels of communication about genome editing in plants in the European regions (per cent)

	Conferences/ discussion events/ workshops	Websites	Technical magazines	Facebook***	Twitter*	Newspapers**	Scientific journals	Radio/TV	Blogs/forums/ podcasts	YouTube
WEC ($n = 91$)	71.1	48.5	39.1	22.7	34.8	28.2	21.8	15.9	12.6	9.7
NEC ($n = 19$)	88.4	64.1	46.1	60.8	59.1	70.3	18.2	50.3	37.5	23.5
EEC ($n = 26$)	61.7	60.3	36.5	60.3	9.9	17.1	18.8	36.5	24.7	23.8
SEC ($n = 24$)	65.6	34.1	43.2	47.3	40.0	45.5	29.5	46.4	10.5	1.8

Data source: Merged data from Study A and B.

*, **, *** indicate significant differences at $p \leq 0.05, 0.01, 0.001$ according to chi-square test.