12-2021

CRISPR Gene Editing Drivers, Barriers and Prospects: A Comparative Study among Plant Scientists Globally

Adriaan Johannes de Lange
University of Arkansas, Fayetteville

CRISPR Gene Editing Drivers, Barriers and Prospects: A Comparative Study among Plant Scientists Globally

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Agricultural Economics

by

Adriaan Johannes de Lange
Wageningen University & Research
Bachelor of Science in Management and Consumer Studies, 2018

December 2021
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Lawton Lanier Nalley, Ph.D.
Thesis Director

Hans de Steur, Ph.D.
Committee Member

Aaron Michael Shew, Ph.D.
Committee Member

Abstract

The introduction of CRISPR gene editing into food crops has potential to contribute to food security and sustainable food production globally. To date, most scientific studies have focused on consumer perception of CRISPR gene edited foods or the potential benefits and risks of the CRISPR technology and none have focused on the perceptions of plant scientists concerning CRISPR gene editing. This study aimed to explore the investments, functions, barriers, benefits for specific crops and beneficiaries of CRISPR gene editing according to plant scientists, by distributing an online survey in which 1,040 plant scientists active across six continents and in both the public and private sector participated. By asking the respondents the current (and envisioned future) percentage of the total research and development that is spend on CRISPR gene editing, we found that relative investments in CRISPR gene editing are expected to increase in the next ten years in all continents and in both the public and private sector. Moreover, plant scientists expect that *fungus resistance* and *virus resistance* are the functions most likely to be implemented using CRISPR technology. *Consumer perceptions/knowledge gap* and *policy/legal issues* were perceived as the most impeding barriers of CRISPR adoption globally, where *intellectual property rights issues* are a major impediment in high-income countries and *high development costs* in low-income countries. M*aize* and *soybean* are expected to benefit the most from CRISPR gene editing across all regions, except for Oceania. *Wheat*, *rice* and *potatoes* are other crops in which plant scientists see potential to benefit from the CRISPR technology. *Increased yields* are expected to be the biggest beneficiary of CRISPR gene editing, where public scientists also see *producer profits* as an important beneficiary of the technology. Importantly, plant scientists are reluctant to the idea of CRISPR gene editing being regulated in a similar way as GM crops and expect the private sector to dominate the CRISPR market. The consensus among plant scientists is that CRISPR technology can contribute significantly to the enhancement of environmental sustainability and food insecurity issues.

Acknowledgments

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics issued by the University of Arkansas (United States of America) and the joint academic degree of International Master of Science in Rural Development from Ghent University (Belgium), Agrocampus Ouest (France), Humboldt University of Berlin (Germany), Slovak University of Agriculture in Nitra (Slovakia), University of Pisa (Italy) and University of Córdoba (Spain) in collaboration with Can Tho University (Vietnam), Escuela Superior Politécnica del Litoral (Ecuador), Nanjing Agricultural University (China), University of Agricultural Science Bengaluru (India), University of Pretoria (South-Africa) and University of Arkansas (United States of America).

This thesis was elaborated and defended at the University of Arkansas within the framework of the European Erasmus Mundus Joint Master Degree International Master of Science in Rural Development (Course N° 2019 – 1507 / 001 – 001) and the EU-US Cooperation Programme in Higher Education and Vocational Training (Transatlantic Degree Consortia Projects) nr. 2008-1745/001 – 001 CPT-USTRAN and the Fund for the Improvement of Postsecondary Education (EU-US Atlantis Program grant P116J080034, U.S. Department of Education). However, the contents of the thesis do not necessarily represent the policy of the supporting agencies, and you should not assume endorsement by the supporting agencies.

I would like to express my appreciation to Dr. Lanier Nalley (Uark), for his extremely valuable guidance, feedback and support in this research which mainly was conducted remotely due to the COVID pandemic. Also, I would like to thank my co-promotors Prof. Hans de Steur (Ugent) and Dr. Aaron Shew (Uark) for their valuable and constructive feedback and support during the research process. I would like to thank Wei Yang (Uark) for his cooperation and support during the data analysis of this research. I would also like to thank all the 1040 respondents of the research survey who took the time and effort to contribute to this project. Moreover, I would like to express my appreciation to those who enabled my studies in the Atlantis Program: Alicia Minden, Dr. Ahrendsen, Dr. Rainey, Dr. Speelman and Iarre Lafort.

Table of Contents

Introduction

Global food production is under increasing pressure from multiple external factors, including climate change (Hasegawa et al., 2021; Müller et al., 2011; Ray et al., 2019; Rosenzweig et al., 2014), population growth (Charles et al., n.d.; Ray et al., 2013; Tilman et al., 2011; United Nations - Department of Economic and Social Affairs, 2019; van Dijk et al., 2021) and water scarcity (Dolan et al., 2021; Falkenmark, 2013; FAO, 2012). Weather and climate volatility are expected to increase with global climate change, resulting in the emergence and growth of new and existing viruses (Chakraborty & Newton, 2011; Chaloner et al., 2021; Karpicka-Ignatowska et al., 2021) and pests (Barford, 2013; Bebber et al., 2013; Ma et al., 2021), which have the potential to reduce agricultural productivity (FAO, 2020). The Intergovernmental Panel on Climate Change (IPCC) hypothesizes that heat thresholds for agriculture will be exceeded more frequently and for longer durations as temperatures globally are rising further threating agricultural production and global food security (Hasegawa et al., 2021; IPCC, 2021; Lesk et al., 2016; Verschuur et al., 2021).

Furthermore, the global population is expected to increase up to 9.7 billion people in 2050 (United Nations - Department of Economic and Social Affairs, 2019), increasing the demand for food globally between an estimated 36% and 56% between 2010 and 2050 (van Dijk et al., 2021). This increase, in combination with the external pressure from climate change, water scarcity and an increasing number of crop pests and diseases puts heavy pressure on agricultural production worldwide to keep up with demand. Especially seen in the light of food security, production solutions are needed to ensure a sustainable and sufficient agricultural production globally.

Between 720 and 811 million people suffer from chronical undernourishment globally in 2020, an increase of 118 up to 161 million people compared to 2019 and 9,9 percent of the global population. The FAO estimates that almost one-third of the global population did not have access to adequate food in 2020 (FAO, 2021). Plant breeding is seen as one of the most significant contributors to yield increases in agricultural production in the last decades and one of the greatest tools to decrease global food security (Qaim, 2016). According to Evenson and Gollin (2003), modern seed varieties contributed almost 21% to the agricultural production growth in developing countries, highlighting the importance of plant breeding in global food security. The Green Revolution was a period from 1960 to 2000 in which modern high-yielding crop varieties (MVs) were developed, to support developing countries in their objective to reduce food insecurity. The introduction of new high-yielding rice and wheat varieties led to up to tripled production numbers in Latin-America and Asia, resulting in increased food security in these areas (Evenson & Gollin, 2003; Pingali, 2012; Qaim, 2016). Despite the successes, critics argue that the Green Revolution also had negative impacts on the sustainability of agriculture, due to the intensive use of fertilizers, increased water consumption and degradation of the soil (Evenson & Gollin, 2003; John & Babu, 2021; Pingali, 1994, 2012).

New plant breeding techniques and their role in the future of agriculture

Currently, New Plant Breeding Techniques (NPBTs) are emerging as a response to both the increasing global food demand and increasing pressure on the environment (Enfissi et al., 2021; Qaim, 2020; Schaart et al., 2015; Shan-e-Ali Zaidi et al., 2019; Smith et al., 2021; Van de Wiel et al., 2018). These new breeding techniques consist of e.g. cisgenesis (Van de Wiel et al., 2018), induced early flowering (Schaart et al., 2015), agro-infiltration (Enfissi et al., 2021), genetic modification (Klümper & Qaim, 2014; Zilberman et al., 2015, 2018) and gene editing (Qaim, 2020; Shan-e-Ali Zaidi et al., 2019; Smith et al., 2021). Genetic modification (GM) of crops, has spread rapidly across major agricultural production areas in the last decades. In the 1980s the technology came up in the agri-biotechnology industry, quickly attracting the interest of the public (Barrows et al., 2014). Genetic modification of crops is described by the Food and Agricultural Organization of the United Nations (FAO) (FAO, 2011) as: 'An organism in which one or more genes (called transgenes) have been introduced into its genetic material from another organism using recombinant DNA technology. For example, the genes may be from a different kingdom (such as from a bacterium to a plant) or a different species within the same kingdom (e.g. from one plant species to another)' (FAO, 2011). The technology allows that the DNA of an organism (e.g. food crops) can be manipulated and transferred to another organism. Through this transferring, preferred traits of an organism can be introduced into another organism (Raman, 2017). Some functions and benefits of GM include: pest resistance, biofortification of crops (Zilberman et al., 2018), herbicide tolerance (Klümper & Qaim, 2014) and improved resistance to insect pests and viral infections (Brookes & Barfoot, 2020). According to Brookes & Barfoot (2020), the introduction of GM has resulted in a 8.3% reduction in pesticide use worldwide and an almost 23 million kg reduction in carbon emissions in 2018 globally. Despite the perceived benefits, and GM already being deployed by more than 17 million farmers worldwide (Brookes & Barfoot, 2020), controversy surrounds the technology. Critics are concerned about the impact of GM on biodiversity and the ecology (Uzogara, 2000), biosafety and the health risks for consumers (Kumar et al., 2020), the effects on non-targeted organisms and the dominance of five multinationals (Monsanto, Syngenta, Bayer CropScience, Dupont & Limagrain) who own 70% of the GM seed market, which raises concerns about possible exploitation of farmers (Kumar et al., 2020). This criticism has led to mixed public acceptance of GM crops (Cui & Shoemaker, 2018) and strict regulation of genetically modified organisms, particularly in the European Union, raising the costs for commercialization significantly (Shew et al., 2018).

Gene editing (GE) technologies, allow plant scientists to alter, delete and/or add genetic material at site-specific locations in the gene of a living organism. Key differences between GM and GE are that GE technologies can make more accurate site-directed insertions in the DNA and that the insertion of foreign DNA from another organism (transgenesis) is less common in gene editing technologies (Ding et al., 2016; Martin-Laffon et al., 2020; Qaim, 2019; Ricroch, 2019). Examples of existing gene editing technologies are transcription activator-like effector nucleases (TALENs), Zinc-finger nucleases (ZFNs) and clustered regulatory interspaced short palindromic repeat (CRISPR). TALENs use engineered nucleases to make double-strand breaks (DSBs) at specific locations in the gene of a living organism. These breaks are repaired and sequence alterations can be created (Joung & Sander, 2013). ZFNs are programmable nucleases consisting of DNA-binding zinc-finger proteins, which are used to cut the DNA. ZFNs have relatively high off-target effects (M. Song et al., 2014).

Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) are found in the immune system of bacteria and archaea. This immune system, has the ability to find and exterminate unwanted DNA in a highly effective and specific manner (Li et al., 2016). CRISPR allows scientists to delete certain viruses from plants and make diseases inheritable for humans and animals (Jiang & Doudna, 2017; Manghwar et al., 2019; G. Song et al., 2016). Examples are the improved resistance again rice blast in China (Wang et al., 2016), the elimination of HIV-1 genomes from human cells using CRISPR (Kaminski et al., 2016) and the increase of the shelf-life of tomatoes (Yu et al., 2017). CRISPR is especially known for its simplicity and adaptability (R. K. Joshi et al., 2020). TALENs and ZFNs are protein-dependent DNA cleavage systems, whereas CRISPR falls under the RNA-dependent DNA cleavage systems category (K. Zhang et al., 2017). Also, variation introduced through CRISPR technology can be indistinguishable from variations that occur naturally, making it very difficult to know which crops have been edited using CRISPR gene editing (Chilcoat et al., 2017).

CRISPR gene editing applications and controversy

Potential functions of CRISPR technology are herbicide resistance (Ricroch et al., 2017), drought resistance (Chilcoat et al., 2017), salt soil tolerance (Farhat et al., 2019), insect resistance (Zahoor et al., 2021), biofortification (Chilcoat et al., 2017; Jia & Nian, 2014; Ricroch et al., 2017), fungus resistance (Ricroch et al., 2017), virus resistance (Ali et al., 2016; Wang et al., 2016), increased shelf life (Yu et al., 2017), fertilizer use efficiency (Tiwari et al., 2020a) and improved cultivation of crops, all of which have potential to reduce global food insecurity and improve sustainability of agricultural production.

The technology has the potential to contribute to the solutions of problems encountered in food production globally, especially in developing countries. Feasible beneficiaries of CRISPR gene editing are reduced food insecurity (S. Ahmad et al., 2021; Georges & Ray, 2017b; Karavolias et al., 2021; Massel et al., 2021b; Y. Zhang et al., 2019; Zhu et al., 2020), reduced environmental damage in agricultural production (S. Ahmad et al., 2021; Biswas et al., 2021b; Georges & Ray, 2017b; Karavolias et al., 2021; Massel et al., 2021b; Y. Zhang et al., 2019; Zhu et al., 2020), increased nutritional value in crops (S. Ahmad et al., 2021; Biswas et al., 2021b; Karavolias et al., 2021; Zhu et al., 2020), increased producer profits (S. Ahmad et al., 2021; Van der Oost & Fresco, 2021) and increased yields and reduced yield variability (S. Ahmad et al., 2021; Biswas et al., 2021b; Georges & Ray, 2017b; Karavolias et al., 2021; Zhu et al., 2020).

Despite the perceived benefits of CRISPR, like GM, the technology has also caused controversy among consumers, policymakers and agricultural producers. Perceived risks and barriers of CRISPR gene editing implementation are policy/legal issues around CRSPR gene editing (Andoh, 2017; Menz et al., 2020; Purnhagen, 2018; Smyth et al., 2014), struggling to find competent delivery methods (F. Zhang et al., 2014), lack of fundamental knowledge on gRNA design (Masmitjà et al., 2019; Wilson et al., 2018), intellectual property right issues (Martin-Laffon et al., 2019; Mulvihill et al., 2017), lack of knowledge and misunderstanding among consumers (Ishii & Araki, 2016; Shew et al., 2018), the risk of off-target effects (N. Ahmad et al., 2020; Graham et al., 2020; X. H. Zhang et al., 2015), the creation of gene drives (Dolezel et al., 2020; Noble et al., 2017) and the high costs of the technology and subsequently underdeveloped infrastructure and technical expertise. This controversy, has led to the decision of the European Union (EU) to make CRISPR gene edited crops subject to strict GM regulations, limiting the applications of the technology and significantly increasing the costs of commercialization of CRISPR gene edited crops (Purnhagen, 2018; Purnhagen & Wesseler, 2020). Other countries like Argentina and the United States of America use a case-by-case judgement system to assess whether a CRISPR gene edited organism is GM or not. The United States Department of Agriculture (USDA) exempted 35 out of the 86 inquiries since 2010, using genome editing. Examples are genome edited canola and soybeans with modified oil composition using TALEN. In Argentina, a producer must proof the absence of a transgene in the crop in order to be exempted from GMO regulation (Menz et al., 2020).

Wageningen University & Research, one of the leading agricultural research institutes and universities, is the first institution to freely license its CRISPR patents as they believe it can play a pivotal role in fighting food insecurity and climate change (Van der Oost & Fresco, 2021). The potential of CRISPR to combat global food insecurity and its controversy amongst consumers, producers and regulatory bodies prior to its commercial release highlights the importance of better understanding where and how CRISPR could be implemented in commercial agriculture.

Literature gap in CRISPR research

The majority of current research on CRIPSR gene editing is either about the benefits, risks and barriers of the technology, or the consumer perceptions of (CRISPR) gene edited foods (Ishii & Araki, 2016; Shew et al., 2018). Plant scientists´ voices are heard, as they speak at conferences, join round tables with government officials and publish articles about the importance and/or risks of CRISPR gene editing. However, there lacks a holistic view on where the CRISPR gene editing sector is moving from plant scientists themselves. Therefore, this study aims to serve as the first step of reaching consensus among the global plant science community, about the potential and barriers of the CRISPR gene editing technology, and where and how CRISPR may emerge in commercial agriculture. This study will elicit the perceptions among plant scientists globally about what the major benefits, barriers and prospects of the technology are. These insights can be specified up to continent-, crop-and sector- (public/private) level which can help governments and the plant science industry to implement tailored strategies to overcome the challenges and mitigate the risks of CRISPR gene editing in order to improve food security and make food production more sustainable.

Research questions

In order to fill this literature gap, six research questions were formulated. All results will be specified to region (Africa, Asia, Europe, North America, Oceania and South America) and sector level (private and public).

1. What percentage of the current research and development budgets of plant research institutes/universities/private companies will be invested in CRISPR gene editing?
2. What will be the main functions of CRISPR gene editing?
3. What are, looking at the whole market (both producers and consumers), the main barriers of CRISPR gene editing adoption?
4. Which crops will benefit the most of CRISPR gene editing?
5. Who and/or what will be the main beneficiaries of CRISPR gene editing adoption?
6. Will the CRISPR gene editing sector be public or private sector dominated?

Research methodology and sampling

Target population

The target population of the survey consisted of plant scientists globally. Thus, any scientist active in the field of plant science with working knowledge on plant biology, plant pathology and/or plant breeding were targeted for this survey. Although the targets were heterogeneous in their disciplines (ranging from private to public institutions, working in different regions and on many different crops) they all were assumed to have fundamental technical knowledge on plants and crops and could assess the best what the implications of implementing a technology such as CRISPR are and will be in the food production sector. This assumption was made based on where the contact details of the targeted respondents were collected, at plant science faculties, research institutes, plant science associations and private companies active in plant sciences and biotechnology globally. Importantly, we wanted to target plant scientists across the globe, working in as many crops and cropping regions dealing with different (external) factors such as the climate, consumer acceptance, regulation, and food demands possible.

The question to check whether a respondent was eligible for participation in the survey was (answer options between brackets): *´Are you active in the public or private plant science sector?´ (Public/Private/Both/ I am not active in the plant science sector).* In case the answer to the question was *´I am not active in the plant science sector´* the survey was terminated and the results deleted for the corresponding respondent.

Sampling

To grasp the opinion of these many experts, the research method requires a wide reach as well as quantifiable data in order to answer the research questions. The research participants were targeted through stratified purposeful sampling, which is a form of non-probability sampling (Sandelowski, 2000). This form of sampling is chosen, as the target population of this study has specific traits; they are required to be knowledgeable about plant sciences and the CRISPR gene editing subject. Contact details of plant scientists were derived by conducting extensive online research. The websites of plant scientist platforms, societies, universities and private companies worldwide were (manually) scraped for contact details and listed. Also, the contact details of scientists who published about CRISPR gene editing technology were obtained from the Web of Knowledge database, regardless of whether they were predominantly positive or negative about the gene editing technology. This approach resulted in a database of 6294 e-mail addresses of plant scientists, to whom the survey was distributed using Microsoft Word´s mail merge option. All contact details were publicly available, which likely biased our sample towards the public sector as many private companies do not list individual e-mail addresses. Furthermore, in the e-mail we asked to further distribute the survey to colleagues active in the field of plant sciences, a form of snowball sampling (Leighton et al., 2021). The survey was also shared on

LinkedIn by professors and other contacts aligned to Ghent University and the University of Arkansas, using hashtags (#) such as CRISPR, gene editing, new plant breeding techniques and CRISPRCas9.

Survey method

The complete survey is found in *Appendix 1*. The survey begins with a general introduction asking about the background of the plant scientist in terms of academic level (High school, BSc, MSc, Ph.D., Postdoc, Professorship, Other), activity in the public/private (or both) sectors, years of experience in the plant science sector and the activity in the fundamental or applied sciences. Respondents were then asked which regions their research and development activities of their respective research group/department primarily focuses on (Africa, Asia, Europe, North America, Oceania, South America), and whether their research group/department is active in CRISPR research and development, and if yes, beginning when.

Research and development budget allocation

The respondents were asked to indicate the percentage of the total research and development budget, which their research group or academic department currently allocates towards CRIPSR gene editing, as well as the percentage they envision to be allocated in three, five and ten years in the future. The results of this question can provide insight in the (relative) investments in CRISPR gene editing technology in different regions, among different crops and in the public and private sector. When funding research and development, there are different risks concerning the success of the new technology, such as market risk (competition, low demand, changing market conditions) and technological risk (technology fails to deliver expected results). Therefore, the level of investment in a new technology could provide insight in the level of confidence a program has in the technology (Bodner & Rouse, 2007). Current and anticipated future budget allocations in CRISPR gene editing technology, provide insight in the level of involvement plant scientists, research institutions and biotechnology companies currently have and are estimated to have in CRISPR gene editing. This question is intended to elicit where and by whom, we will see the largest growth in CRISPR funding.

Functions CRISPR gene editing

Participants were then asked about which functions of CRISPR gene editing could have the greatest impact in their region of expertise. The options that participants could choose from were herbicide resistance (Ricroch et al., 2017), drought resistance (Chilcoat et al., 2017), salt soil tolerance (Farhat et al., 2019), insect resistance (Zahoor et al., 2021), biofortification (Chilcoat et al., 2017; Jia & Nian, 2014; Ricroch et al., 2017), fungus resistance (Ricroch et al., 2017), virus resistance (Ali et al., 2016; Wang et al., 2016), increased shelf-life (Yu et al., 2017), fertilizer use efficiency (Tiwari et al., 2020b) and improved cultivation of crops. Because these benefits are not exhaustive, respondents were allowed to add additional functions in the ´Other´ box. Subsequently, the respondents were asked the question:

> *Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in your region of expertise?*

This question was asked for each region separately, thus if a respondent indicated that he or she was active in multiple regions they would answer this question for each specific region they are active in. The respondents rated each function on a Likert scale from 1 (low probability) to 7 (high probability), where 8 represented the ´*I do not know*´ option. The Likert scale was chosen, as it is easy to construct, easy to interpret and complete. Contrary, a weakness may be the that participants avoid extreme responses (Taherdoost, 2019). A seven-point Likert scale was used, which is common in social research, provides nuance in the respondents' answers while at the same time seven attributes is also the maximum a human mind can distinguish at a time (A. Joshi et al., 2015). The results from this question can provide insights in which functions of the CRIPSR gene editing technology could be the most beneficial for each region worldwide and which function could have the highest likelihood of success, between crops and between the public and private sector.

Barriers of adoption CRISPR gene editing

The next section, aimed to elicit which barriers of adoption plant scientists think are the most binding across their region and sector for CRISPR gene editing implementation. The survey questions were again asked separately for each region, and the same Likert scale from 1 (strongly disagree) to 7 (strongly agree) was used. The question was asked as:

> *Given your research activities, please give your opinion about what the major barriers are that impede the large-scale implementation of CRISPR gene editing in your region of expertise.*

The barrier choices were policy/legal issues around CRSPR gene editing (Andoh, 2017; Menz et al., 2020; Purnhagen, 2018; Smyth et al., 2014), struggling to find competent delivery methods (F. Zhang et al., 2014), lack of fundamental knowledge on gRNA design (Masmitjà et al., 2019; Wilson et al., 2018), intellectual property right issues (Martin-Laffon et al., 2019; Mulvihill et al., 2017), lack of knowledge and misunderstanding among consumers (Ishii & Araki, 2016; Shew et al., 2018), the risk of off-target effects (N. Ahmad et al., 2020; Graham et al., 2020; X. H. Zhang et al., 2015), the creation of gene drives (Dolezel et al., 2020; Noble et al., 2017) and the high costs of the technology and subsequently lack of infrastructure and technical expertise. An ´*Other*´ option was not provided for this question as the questions were asked in statement form, see *Appendix 1* for examples. Results from this question can provide the scientific community a better understanding of barriers of adoption of CRISPR gene editing by region and differences between the public and private plant science community.

Benefits for specific food crops

The plant scientists were asked in which food crops they are active, multiple answers were possible. The list of food crop choices in the survey was based on the production data of food crops globally from the Food and Agricultural Organization (FAO, 2019), resulting in the following list of crops: *wheat, maize, soybean, rice, potatoes, cassava, sorghum, millet, yams, plantains, vegetables, fruits, legumes and other*. For *vegetables, fruits, legumes* and *other* there was a text box available, in which the respondent was asked to specify the crop in more detail. As such, the respondents were asked which crops would benefit the most in their opinion from CRISPR gene editing in their region of expertise. The question was formulated as:

> *What is in your opinion the likelihood of the following crops to benefit significantly from CRISPR gene editing technology in your region of expertise?*

The respondents were asked to rate all crops (same crop choices as for the question which dealt with the question in which crop the respondents works) on a Likert scale from 1 (extremely unlikely) to 7 (extremely likely). The respondents were also provided with an *´I do not know´* option. With the results of this question, an assessment could possibly be made on which crops will benefit the most of CRISPR gene editing in a specific region according to the global plant science community.

Beneficiaries CRISPR gene editing

The next portion of the survey dealt with eliciting who and/or what anticipated beneficiaries of CRISPR gene editing would be. Respondents were asked to rate the possible beneficiaries of CRISPR gene editing, by the region of their expertise, on a seven-point Likert scale from 1 (no beneficiary) to 7 (major beneficiary). The question was formulated as:

> *What are (or will be) the major beneficiaries of CRISPR gene editing adoption in your region of expertise?*

The possible beneficiaries, based on previous literature research, were listed as follows: reduced food insecurity (S. Ahmad et al., 2021; Georges & Ray, 2017a; Karavolias et al., 2021; Y. Zhang et al., 2019; Zhu et al., 2020), reduced environmental damage in agricultural production (S. Ahmad et al., 2021; Biswas et al., 2021a; Georges & Ray, 2017a; Karavolias et al., 2021; Massel et al., 2021a), increased nutritional value in crops (S. Ahmad et al., 2021; Biswas et al., 2021b; Karavolias et al., 2021; Zhu et al., 2020), increased producer profits (S. Ahmad et al., 2021; Van der Oost & Fresco, 2021), increased yields and reduced yield variability (S. Ahmad et al., 2021; Biswas et al., 2021a; Georges & Ray, 2017a; Karavolias et al., 2021; Zhu et al., 2020). The answers to this question, could possibly give insight in what the perceived beneficiaries of CRISPR gene editing adoption are and in what regions they will emerge according to the plant scientists. It assists in answering the research question about what the main drivers for CRISPR gene editing adoption are.

Industry consensus on CRISPR gene editing subjects

The public funding of research and development in the agricultural industry, has been reduced in many countries and particularly in the United States (Nature Food, 2020). An exception in this regard, is China where a significant increase of patents can be observed, held and funded by the public sector (Cai et al., 2020). Contrary, private sector investments in the plant science industry globally rose from $5.1 billion to almost $16 billion in the period from 1990 till 2014 (Fuglie, 2016). Some scientists argue that this is an undesirable trend, as the access to new technologies will mainly be for those who can afford it as private companies have a profit orientation (Tripp & Byerlee, 2000; Van der Oost & Fresco, 2021). Currently, the majority of the CRISPR gene editing patents are owned by the United States, China, Japan and multiple European countries. Thirty-three percent of these patents are owned by private companies (Martin-Laffon et al., 2019). Wageningen University & Research has taken the first steps to make the CRISPR gene editing sector more inclusive, by licensing their CRISPR patents free of charge to those who aim to support food security in low-income countries with it (Van der Oost & Fresco, 2021). There exists a debate in the plant science sector on where the gene editing sector should be moving. Thus, insights in where the respondents foresee the technology moving could be of interest for policymakers, agronomists and stakeholders in the industry.

The final part of the survey consists of multiple statements which aim to measure on a seven-point Likert scale from 1 (strongly disagree) to 7 (strongly agree) if the CRISPR gene editing sector is moving into the direction of private sector/multinational dominance or if smaller companies and public institutions like universities can play a significant role, what the main dangers are of CRISPR gene editing adoption and if the technology will be available in developing countries or remains mainly for the biotechnology sector in developed countries. The statements asked to the respondents were:

1. *CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation*
2. *CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues*
3. *CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries*
4. *Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding*
5. *Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market*
6. *CRISPR gene editing patents will primarily be owned by large plant breeding multinationals*
7. *In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology*
8. *The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector*
9. *The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role*
10. *CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries*

Data analysis and statistical testing

After collecting the responses, statistical analyses were performed on the different variables of the survey questions. All questions were answered on a scale from one to seven and consequently a mean score could be derived from every variable in the survey, separated by region and sector. All descriptive statistics were extracted from Qualtrics and compared. Two tests are common to use for Likert-scale data: t-tests and Mann-Whitney tests. Both tests have nearly equivalent Type-I error rates and power (de Winter & Dodou, 2010). Thus, pairwise t-tests were used for further analysis. The statistical analysis focused on the four key questions: functions of CRISPR, barriers of CRISPR implementation, crop benefits and beneficiaries of CRIPSR adoption. The answers to these questions, contain the information to answer the research questions. Also, they lend themselves well for statistical comparison, as all the crops, barriers, functions and beneficiaries received different scores from the respondents which can be compared.

For each variable, a weighted average mean was calculated of all the scores given by the respondents, per region and sector. We chose to use a weighted average mean, because there were differences in number of responses among variables within all questions. Because of the fact this survey contained many variables per question, the decision was made to compare each variable score to the weighted average mean using a pairwise t-test instead of comparing each variable to every other variable in the question. In this way outlying scores could be detected, scores which significantly differ from the weighted average of all scores of e.g. barriers of CRISPR adoption in Africa or the beneficiaries of CRISPR in North America. By this, we could assess whether the respondents rated certain functions, barriers, crop benefits and beneficiaries higher or lower than others, separated by region and sector. Also, some questions contained up to eleven variables, making it almost impossible to test every variable against each other while still being able to draw up comprehensible results.

These tests, show which functions are expected by plant scientists to be successfully or less successfully developed with CRIPSR, which barriers are perceived more or less impeding, which crops will benefit the most from CRISPR gene editing and who or what the main beneficiaries of CRISPR will be. A significance level of five percent was used for all tests. Pairwise t-tests were only run within a region or sector, as comparing between regions and/or sectors is difficult, due to major context differences. However, this research draws a picture on where the major difficulties, opportunities and beneficiaries of CRISPR gene editing lay per region and sector.

Results

Survey responses

The sampling and distribution efforts resulted in 1040 unique responses, of which 669 were usable. Of the entire sample, 371 responses were deleted, for two reasons. Given the length of the survey and thought which was required, any responses under 120 seconds were deleted (47 responses). Also, responses with a completion rate lower than 90 percent were deleted (324 responses). A summary of the profiling variables linked to the 669 participants of this study can be found in *Table 1*.

Table 1: Number of survey respondents, by region and sector

	Africa	**Asia**	**Europe**	**North America**	**Oceania**	**South America**	**Total**
Public	124	76	187	162	13	39	601
Private	37	24	105	40	5	21	232
Both	17	13	23	18	3	4	78
Total	178	113	315	220	21	64	911

*Note: each participant was able to select that they worked in multiple regions, therefore the total of 669 respondents resulted in a total of 911 region and sector counts

Research and development budget allocation towards CRISPR gene editing

The survey results, visualized in *Table 2,* show an interesting development of the investments in CRISPR gene editing technology, according to plant scientists globally. The question which was asked to the respondents was:

> *Could you indicate for your research group/department, what percentage of the total research and development budget is/will be <u>currently/in 3 years/in 5 years/in 10 years</u> allocated to CRISPR gene editing research and development?*

Table 2: Budget allocation towards CRISPR gene editing (in % of the total research and development), separated by region and sector

	Current	in 3 years	in 5 years	in 10 years
All respondents	26,27%	25,05%	29,15%	33,55%
Africa	21,18%	21,77%	27,87%	34,73%
Asia	26,63%	26,76%	32,06%	35,23%
Europe	20,63%	21,29%	24,81%	28,96%
North America	26,08%	23,18%	26,17%	30,62%
Oceania	32,25%	28,06%	34,82%	34,31%
South America	16,53%	19,76%	26,84%	34,12%
Public	26,64%	25,84%	30,39%	34,87%
Private	15,58%	14,17%	20,29%	28,33%

The mean current research and development budget allocation towards (in % of the total research and development budget) CRISPR gene editing according to all respondents who answered the question is slightly higher than a quarter of their total budget, 26,27%. Interestingly, according to the plant scientists participating in this survey this percentage will drop to 25,05% in 3 years. In 5 years the mean allocation of budget towards CRISPR gene editing increases again to 29,15% and reaches 33,55% in 10 years, which equals a more than 7% relative investment increase in CRISPR gene editing globally in the next ten years. While interpreting these results it is important to realize that the presented numbers are relative (% of total research and development budget) and no assumptions about the size of the absolute CRISPR gene editing investments can be derived from the data.

Research and development budget allocation towards CRISPR – Regional trends

Looking at the regional distribution of current and future budget allocations in *Table 2*, multiple differences can be observed. South America (16,53%), Europe (20,63%) and Africa (21,18%) denote the lowest current budget allocations towards CRISPR gene editing technology, whereas the allocations of North America and Asia are around 26,08% and 26,63% respectively with the current allocation in

Oceania being the highest with 32,25%. Interestingly, the envisioned budget allocations in 3 years drop in North America (23,18%) and Oceania (28,06%) compared to their current budget allocations. There is likely selection bias in these numbers in that participants who choose to answer the survey are likely active in gene editing and would represent research groups with higher than average budgets allocated to CRISPR.

The budget of the other regions increase minimally, only South America denotes an increase to 19,76%. The 5 years allocation of budgets increases, compared to the 3 years allocations, with increases across all regions ranging from 2,99% (North America) to 7,08% (South America). In 10 years, African (34,73%), Asian (35,23%), Oceanian (34,31%) and South American (34,12%) plant scientists expect to allocate over more than one-third of their total budget towards CRISPR gene editing technology. North America and Europe remain slightly behind, with allocations of 30,62% and 28,96% respectively. Overall, all budget allocations increase over a ten-year timespan. The highest relative increases between now and ten years in budget allocation towards CRISPR gene editing emerge in South America (17,59%) and Africa (13,55%). The budget allocation in Asia increases 8,6%, in Europe 8,33%, in North America 4,54% and in Oceania 2,06%. It is important when interpreting these results, that these are relative allocations (in % of the total research and development budget)

Research and development budget allocation towards CRISPR – Public/private trends

Table 2 presents the sectoral differences of the allocation of research and development budgets towards CRISPR gene editing. The average current budget allocations were reported at 26,64% for the public sector and 15,58% for the private sector. The allocation decreases in 3 years for both the public sector (25,84%) and the private sector (14,17%), after which the allocation increases in 5 years, a similar pattern as observed earlier in the regional comparison. In 5 years, public sector budget allocation reaches 30,39% and private sector allocation was reported to be on average 20,29%. According to the survey respondents, relative budget allocations towards CRISPR gene editing reach 34,87% for the public sector and 28,33% in the private sector in 10 years. Overall, looking at the difference between the current and in 10 years budget allocations, the growth is 8,23% for the public sector and 12,75% for the private sector according to the survey data. Again, it is important to interpret these results in terms of relative changes and not absolute spending. Since the base amount spent on CRISPR was not asked there is no way to derive total increase in dollars from these estimates.

Functions of CRISPR gene editing

Table 3 highlights the mean scores on the potential of successful implementation of possible functions of CRISPR gene editing can be found, separated by region and sector. Respondents rated the functions on a Likert-scale from 1 (low probability) to 7 (high probability). The question asked was:

> *Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in your region of expertise?*

Functions of CRISPR – A regional comparison

African plant scientists rate *drought resistance*, *insect resistance*, *fungus resistance* and *virus resistance* as the functions of CRISPR gene editing with the highest probability of successful implementation in their region, statistically compared to the weighted mean of all functions in Africa of 3,89. The scores of these functions are significantly higher ($P < 0,05$) than the weighted average of all functions in Africa. Contrary, *salt soil resistance*, *fertilizer use efficiency* and *improved cultivation* were rated significantly lower as possible successful functions of CRISPR in Africa. These non-significant scores do not indicate the specific function is not important, just unlikely to be successfully implemented. Successful implementation could be due to targeted funding, the severity of an issue or the number of plant scientists working on said issue. The survey did not set out to explain why an issue was important but rather what issue(s)/function(s) plant scientists thought would be successfully addressed via CRISPR.

In Asia, *fungus resistance and virus resistance* are the highest rated functions, whereas *fertilizer use efficiency* is seen as least viable function of the CRISPR technology in the Asian context according to plant scientists active in the region. All functions were statistically compared to the weighted mean of all functions in Asia of 3,95.

Plant scientists with research programs focusing on European agriculture, see *drought resistance*, *insect resistance*, *fungus resistance* and *virus resistance* as the most likely functions to be successfully implemented, statistically compared to the weighted mean of all functions in Europe of 3,56. Interestingly, all other functions score significantly lower than the weighted average mean, ranging from 2,28 to 3,28.

North American plant scientists indicated that *herbicide resistance* will likely be the most successful function with a score of 5,02, the only function score exceeding five across all regions and sectors. *Fungus resistance* and *virus resistance* reported significant higher scores as well, with 4,96 and 4,74, respectively. On the other end *salt soil resistance*, *biofortification*, *fertilizer use efficiency* and *improved cultivation* score significantly lower than the weighted average function score in the North American region. All functions in North America were statistically compared to the weighted mean of all functions, 4,00.

Oceania and South America denoted no significant differences compared to the weighted average function score of their regions. Again, this lack of statistical difference does not indicate that CRISPR would have low probability of success/adoption in these areas, rather that there is no obvious function in which CRISPR may be targeted.

Overall, four regions (Africa, Asia, Europe and North America) denoted significant higher scores for *fungus resistance* and *virus resistance* and significant lower scores on *fertilizer use efficiency* as possible function of CRISPR gene editing. *Drought resistance* and *insect resistance* seem to be viable functions of CRISPR in Africa and Europe, where *herbicide resistance* appears to be dominant in North America according to plant scientists.

Functions of CRISPR – A public/private comparison

There seems to be more focus on the potential benefits when comparing private vs. public scientists than comparing those from across different geographical regions of focus. Public sector scientists rated *herbicide resistance*, *drought resistance, fungus resistance* and *virus resistance* as the most likely functions to be implemented successfully, regardless of the region they are to be implemented in. Contrary, *salt soil resistance*, *fertilizer use efficiency* and *improved cultivation* are not looked at as very feasible functions of CRISPR gene editing across the public sector globally. All functions of the public sector were statistically tested to the weighted mean of all functions of the private sector, being 3,87.

At private sector level *insect resistance*, *fungus resistance*, *virus resistance* and *increased shelf life* are perceived as the functions with the highest probability of successful implementation. *Salt soil resistance*, *biofortification* and *fertilizer use efficiency* are rated the lowest in the private sector. All functions of the private sector were statistically tested to the weighted mean of all functions of the private sector, being 3,51.

Overall, the sectors rate multiple functions comparable. Differences mainly lay in the fact that the public sector sees *herbicide resistance* and *drought resistance* as feasible functions of CRISPR, whereas the private sector rated these traits not significantly higher than the weighted mean.

Table 3: Plant scientists' opinions on the functions of CRISPR gene editing technology, rated on a scale from 1 (low probability) to 7 (high probability)

	Africa (σ=3,89) **		Asia (σ=3,95) **		Europe (σ=3,56) **		North America (σ=4,00) **		Public (σ=3,87) **		Private (σ=3,51) **	
Functions	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**
Herbicide resistance					3,24	291	5,02	196	4,19	540		
Drought resistance	4,53	168			3,82	295			4,13	560		
Salt soil resistance	2,96	159			3,04	291	3,42	194	3,33	537	2,63	215
Insect resistance	4,42	161			4,01	290			4,21	541	4,00	215
Biofortification					3,07	290	3,52	193			2,62	213
Fungus resistance	4,49	166	4,60	98	4,66	297	4,96	197	4,71	548	4,58	219
Virus resistance	4,85	164	4,81	100	4,46	294	4,74	196	4,62	542	4,61	217
Increased shelf life					3,28	291						
Fertilizer use efficiency	3,26	162	3,27	94	3,18	288	3,43	195	3,29	536	3,01	214
Improved cultivation	3,45	159			3,23	291	3,34	196	3,33	536		
Other****		62			2,28	106			2,35	191	2,38	93

* The presented values denote an issue of the corresponding variable which was statistically (P<0.05) higher (green font) or lower (red font) than the weighted average of all functions of CRISPR implementation of the corresponding region/sector. An empty cell denotes no statistical difference was found

** The σ denotes the weighted average of the aggregated functions of the corresponding region/sector

*** No significant differences from the weighted average mean were found for South America and Oceania, therefore these results are not included in *Table 3*

**** *Other* consists of answers the respondents were allowed to put forward themselves, examples are: *acid soil tolerance*, *improved seed quality* and *nitrogen fixation*

Barriers of CRISPR adoption

Table 4 shows the perceived barriers of CRISPR gene editing implementation, across different regions and sectors. The survey participants rated nine barriers on a Likert-scale from 1 (strongly disagree) to 7 (strongly agree) which resulted in a mean score for every barrier. The question asked was:

> *Given your research activities, please give your opinion about what the major barriers are that impede the large-scale implementation of CRISPR gene editing in your region of expertise.*

Barriers of CRISPR adoption – A regional comparison

African plant scientists, foresee multiple barriers as significantly more impeding than others. *Policy/ legal issues* was rated the highest with a score of 5,80, closely followed by *lack of infrastructure/technical expertise* (5,71). *High development costs* and *consumer perceptions/knowledge* gap were the other two barriers that scored significantly higher than the weighted mean, with a score higher than five. Conversely, *off-target effects, gene drives* and *gRNA design* were scored significantly lower than the weighted average of all barriers of CRISPR gene editing implementation in Africa. All barriers in Africa were statistically compared to the weighted mean of all barriers in Africa, being 4,97.

In Asia, *policy/legal issues* are considered as the most impeding barrier of CRISPR gene editing implementation, followed by *consumer perceptions/knowledge gap*. *Intellectual property rights issues* is another barrier considered as more impeding than the weighted average of all barriers in Asia (4,24). *Off-target effects*, *gRNA design* and *lack of infrastructure/technical expertise* are considered less impeding than the weighted average of all barriers in Asia.

European plant scientists who were surveyed rated *policy/legal issues* as the most impeding barrier of CRISPR gene editing implementation, with a score of 6,72 it is the highest rated barrier across all regions and both the public and private sector. *Consumer perceptions/knowledge gap* denoted a significant higher score than the weighted average with 5,91 as well, followed by *intellectual property* *rights issues*. Interestingly, all other barriers were rated significantly lower than the weighted average mean of all barriers (4,12) by plant scientists with expertise in European agriculture.

North American plant scientists rate *policy/legal issues*, *consumer perceptions/knowledge gap* and intellectual property rights issues significantly higher than the weighted mean of all barriers in the North American region (3,98). The other barriers were all rated significantly lower than the weighted average of all barriers in the region, except for *high development costs* and *delivery methods* for which no differences from the weighted average were found.

In Oceania *policy/legal issues* and *consumer perceptions/knowledge gap* were considered as the most impeding barriers of CRISPR gene editing implementation, with scores of 5,22 and 5,18 respectively. The only significant lower score than the weighted mean was found for *gRNA design*. All barriers in Oceania were statistically compared to the weighted mean of all barriers in Africa, being 3,98.

Respondents with expertise in South America, rated *consumer perceptions/knowledge gap* and *high development costs* as the biggest impediments of CRISPR adoption in the region. *Off-target effects* are considered as least impeding in the South American plant science industry. The weighted mean of all barriers in South America was 4,10.

Across all regions, *consumer perceptions/knowledge gap* is considered as a significant more impeding barrier than the weighted average of all barriers in the corresponding region. *Policy/legal issues* is rated significantly higher than the weighted average of the corresponding region in all regions, except South America. *Intellectual property rights issues* is rated as highly impeding in Asia, Europe and North America. Not surprisingly, we see that *high development costs* is considered as a barrier in Africa and South America. Contrary, *off-target effects* scores significantly lower in all regions, except Oceania. The barrier *gRNA design* denotes low scores as well in all regions, except in South America. *Lack of infrastructure/technical expertise* denotes low scores in the most developed regions in terms of CRIPSR gene editing, Asia, Europe and North America.

Barriers of CRISPR adoption – A public/private comparison

Plant scientists active in the public sector listed, in this order, *policy/legal issues, consumer perceptions/knowledge gap* and *intellectual property rights issues* as significantly most impeding barriers of CRISPR gene editing. All other barriers score significantly lower than the weighted average barrier score of the public sector, except for *delivery methods* and *high development costs* for which no differences from the weighted mean were found. All barriers were tested against the weighted mean of 4,31.

In the private sector, *policy/legal issues*, *consumer perceptions/knowledge gap* and *intellectual property rights issues* are considered as most impeding. Unlike the public sector, the private sector also considered *high development costs* as significantly more impeding than the mean of all barriers. All other barriers are scored significantly lower than the weighted average mean, being 4,09.

The public and private sector plant scientists exhibited similar patterns when it comes to the perception of barriers of CRIPSR gene editing adoption. The key difference is that the private sector considers *high development costs* as a more impeding barrier compared to other barriers as well, where the public sector does not. Also, no differences were found for *delivery methods* in the public sector, where the private sector scores this barrier as significantly lower than the weighted average mean of all barriers in the private sector.

Table 4: Plant scientists' opinions on the barriers of CRISPR gene editing technology, rated on a scale from 1 (strongly disagree) to 7 (strongly agree)

	Africa (σ=4,97) **		Asia (σ=4,24) **		Europe (σ=4,12) **		North America (σ=3,98) **		Oceania (σ=3,98) **		South America (σ=4,10) **		Public (σ=4,31) **		Private (σ=4,09) **	
Barriers	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**
Policy/legal issues	5,80	169	5,45	99	6,72	307	4,48	201	5,22	18			5,70	561	5,65	217
Delivery methods					3,88	295									3,58	217
gRNA design	4,59	169	3,15	97	2,88	296	3,29	197	2,50	18			3,45	561	3,15	217
Intellectual property rights			4,80	94	4,46	299	4,45	198					4,57	561	4,38	217
Consumer perceptions/ knowledge gap	5,46	167	4,98	96	5,91	301	5,29	198	5,18	17	5,04	51	5,51	561	5,40	217
Off-target effects	3,83	167	3,75	96	3,43	295	3,37	200			3,14	50	3,56	561	3,37	217
Gene drives	3,87	168			3,37	299	3,55	199					3,62	561	3,46	217
High development costs	5,67	166			3,58	298					4,78	51			4,36	217
Lack of infrastructure/ technical expertise	5,71	170	3,79	98	2,75	297	3,30	199					3,78	555	3,45	217

* The presented values denote an issue of the corresponding variable which was statistically ($P<0.05$) higher (green font) or lower (red font) than the weighted average of all barriers of CRISPR implementation of the corresponding region/sector. An empty cell denotes no statistical difference was found

** The σ denotes the weighted average of the aggregated barriers of the corresponding region/sector

Benefits of CRISPR gene editing for specific crops

In *Table 5,* the results on the benefits for specific crops are presented by region and sector. Respondents rated eight crops (respondents could introduce additional crops through the *Other* option) on a scale from 1 (extremely unlikely) to 7 (extremely likely). The question asked was:

> *What is in your opinion the likelihood of the following crops to benefit significantly from CRISPR gene editing technology in your region of expertise?*

Crop benefits – A regional comparison

African plant scientists, rate three crops as the (significant) likeliest to benefit from CRISPR gene editing in their region*.* *Maize* is the rated the highest compared to the other crops, with a score of 5,98. *Soybean* (5,13) and *cassava* (4,97) were also statistically higher than the average of all crops likely to benefit from CRISPR. One crop is rated significantly lower than the weighted average score of all crops in Africa (4,46), which is *plantains*.

Respondents with expertise in the Asian region, see the most potential in (in this order): *rice*, *soybean*, *maize*, *wheat* and *potatoes*, respectively. *Rice* received the score of 6,33, which is the highest score of all crops across all regions. All other crops in Asia were rated significantly lower than the weighted average score of 4,21.

For the European region, four crops scored significantly higher than the weighted mean of all crops (3,40): *wheat*, *maize*, *potatoes* and *soybean*. All other crops received a significant lower score, except for *rice* for which no statistical difference from the weighted mean was found.

In North America, five crops were indicated as most likely to benefit from CRISPR gene editing. *Maize*, *soybean*, *wheat*, *potatoes* and *rice* scored statistically higher than the weighted average of all crops in North America. Not surprisingly, *cassava* and *plantains* scored significantly lower.

In Oceania, no statistical different scores from the weighted average mean of 3,32 were observed.

In South America, *soybean* was expected to benefit significantly from CRISPR gene editing with a score of 6,26. *Maize*, *rice* and *wheat* were also expected to benefit significantly more from the technology than other crops. All other crops are predicted to benefit less, except for *potatoes* for which no statistical differences from the weighted mean of 3,80 were found.

Overall, a clear trend can be observed regarding the crop benefits. In all regions except Oceania, *maize* and *soybean* are expected to benefit significantly more than other crops from CRISPR gene editing. *Wheat* scores significantly higher in all regions, except for Africa and Oceania. Furthermore, *rice* is expected to benefit significantly more compared to the other crops in Asia, North America and South America. *Potatoes* are expected to benefit in Asia, Europe and North America, whereas *cassava* is only expected to benefit from CRISPR gene editing in Africa. *Plantains* is not expected to benefit exceptionally from the technology in any of the regions. Also, *other* crops were not rated significantly higher in any of the regions.

Crop benefits – A public/private comparison

Looking at sectoral level, comparable results between the public and private sector were found. In both sectors *wheat*, *maize*, *soybean* and *potatoes* scored significantly higher than the weighted average crop benefit score of the corresponding sector (3,98 for public, 3,66 for private). Also, *cassava*, *plantains*, *sorghum* and *other* scored significantly lower in both sectors. The only difference between the two sectors is the fact that a significant higher result emerged for *rice* in the public sector, whereas in the private sector no statistical differences were found for *rice*.

Table 5: Plant scientists' opinions on the benefits for specific crops of CRISPR gene editing technology, rated on a scale from 1 (extremely unlikely) to 7 (extremely likely)

	Africa (σ=4,46) **		**Asia (σ=4,21) ****		**Europe (σ=3,40) ****		**North America (σ=3,98) ****		**South America (σ=3,80) ****		**Public (σ=3,98) ****		**Private (σ=3,66) ****	
Crop Benefits	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**
Wheat			5,16	86	5,14	277	5,15	179	4,76	46	4,96	513	5,26	186
Maize	5,98	162	5,51	81	5,13	275	6,10	174	5,87	46	5,61	508	5,72	189
Soybean	5,13	155	5,60	81	4,50	268	6,07	178	6,26	46	5,20	505	5,38	183
Rice			6,33	88			4,70	176	4,87	46	4,71	504		
Potatoes			4,94	83	5,12	274	4,74	178			4,74	508	5,02	191
Cassava	4,97	159	3,29	80	1,90	262	2,50	173	2,84	45	3,18	498	2,27	183
Sorghum			3,49	81	2,48	263			2,69	45	3,50	498	2,93	183
Plantains	3,90	157	2,43	79	1,71	260	2,09	172	2,32	44	2,53	492	1,98	181
Other****	3,66	593	3,34	316	2,71	1032	3,16	698	2,80	149	3,24	1877	2,76	704

* The presented values denote an issue of the corresponding variable which was statistically ($P<0.05$) higher (green font) or lower (red font) than the weighted average of all crop benefits of CRISPR implementation of the corresponding region/sector. An empty cell denotes no statistical difference was found

** The σ denotes the weighted average of the aggregated crop benefits of the corresponding region/sector

*** No significant differences from the weighted average mean were found for Oceania, therefore these results are not included in *Table 5*

**** *Other* consists of answers the respondents were allowed to put forward themselves, examples are: *quinoa*, *sugarcane*, *sunflower* and *coffee*

Beneficiaries of CRISPR gene editing

Table 6 presents the results on the perceived beneficiaries of CRISPR gene editing according to plant scientists globally. Six answer options were provided to the respondents as well as an *Other* option. These options were rated on a scale from 1 (no beneficiary) to 7 (major beneficiary). The question asked was:

> *What are (or will be) the major beneficiaries of CRISPR gene editing adoption in your region of expertise?*

Beneficiaries of CRISPR – A regional comparison

Analyzing the results of the beneficiaries question, it can be observed that little statistical differences were found across all regions. In Africa, only *yields* is rated higher than the weighted average of 3,76 of all beneficiaries in the region. In Europe and North America, *food insecurity* scores statistically lower than the weighted average, whereas *yields* scores significantly higher than the weighted mean in both regions. All beneficiary scores were statistically compared to the weighted mean of all beneficiaries in the corresponding region, being 3,94 for Europe and 3,96 for North America. In Asia, Oceania and South America, no statistical differences were found, meaning that all beneficiary options were scored highly comparable.

Beneficiaries of CRISPR – A public/private comparison

In both the public and private sector *yields* denoted significant higher scores than the weighted average scores of the corresponding sector (3,98 for the public sector, 3,66 for the private sector). For the public sector, *producer profits* denoted a statistically higher score as well, whereas *reduced food insecurity* denoted a significant lower score than the weighted mean. In the private sector no statistical differences were found for these two variables.

Table 6: Plant scientists' opinions on the beneficiaries of CRISPR gene editing technology, rated on a scale from 1 (no beneficiary) to 7 (major beneficiary).

	Africa (σ=3,76) **		**Europe (σ=3,94) ****		**North America (σ=3,96) ****		**Public (σ=3,98) ****		**Private (σ=3,66) ****	
Beneficiaries	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**	**Mean**	**# of responses**
Reduced food insecurity			3,33	295	3,25	186	3,39	540		
Environmental damage agriculture										
Increased nutritional value in crops										
Producer profits							4,16	535		
Increased yields	4,16	171	4,33	293	4,39	187	4,33	540	4,24	207
Yield variability										
Other****										

* The presented values denote an issue of the corresponding variable which was statistically ($P<0.05$) higher (green font) or lower (red font) than the weighted average of beneficiaries of CRISPR implementation of the corresponding region/sector. An empty cell denotes no statistical difference was found

** The σ denotes the weighted average of the aggregated beneficiaries of the corresponding region/sector

*** No significant differences from the weighted average mean were found for Asia, South America and Oceania, therefore these results are not included in Table 6

**** Other consists of answers the respondents were allowed to put forward themselves, examples are: *improved quality of produce*, *reduced biotic stresses* and *reduced use of agro-inputs*

Industry consensus on CRISPR gene editing subjects

Table 7, shows the scores on different statements concerning multiple topics such as CRISPR regulation, CRISPR market structures and risks of CRISPR gene editing that were asked to the survey respondents. These statements were rated on a seven-point Likert scale from 1 (strongly disagree) to 7 (strongly agree). No statistical tests were performed on these variables. However, multiple trends can be observed. The first statement compared CRISPR gene edited and GM crops, which was formulated as:

CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation

Across both sectors and all regions, scientists score the statement lower than three, except for Africa with a score of 3,31. This corresponds with a result between *disagree (2)*, *somewhat disagree (3)* and *neither agree nor disagree (4)*.

Another statement with high scores across all regions and sectors, was the statement regarding the potential of CRISPR gene editing to be a major contributor to the solutions of food insecurity and environmental issues. It was formulated as:

CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues

Scores ranged across all regions and sectors between 5,86 and 5,98. This corresponds with a result between *somewhat agree (5)* and *agree (6)*. On average, respondents agree across all regions and sectors that CRISPR gene editing can be one of the major contributors to the solutions of these issues.

The last statement that will be highlighted, is concerning the private sector dominance in the CRISPR gene editing market. It was formulated as:

The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector

Scores ranged between 4,90 (Asia and Oceania) and 5,45 (private sector) across all regions and sectors. This corresponds with a result of *neither agree nor disagree (4), somewhat agree (5)* and *agree*

(6). There seems to be consensus among plant scientists globally, that the private sector will be the more dominant actor in the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector.

Overall, these statements indicated that plant scientists globally are reluctant to the idea of CRISPR gene editing being regulated in a similar way as GM crops, have confidence in the hypothesis that CRISPR gene editing can be one of the major solutions to environmental and food insecurity issues and believe that the private sector will be the more dominant player in the CRISPR market rather than the public sector.

Table 7: Plant scientists' opinions on multiple statements concerning CRISPR gene editing technology, rated on a scale from 1 (strongly disagree) to 7 (strongly agree)

	Africa	**Asia**	**Europe**	**North America**	**Oceania**	**South America**	**Public**	**Private**
	Mean	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	3,31	2,90	2,52	2,86	3,00	2,76	2,88	2,88
CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	5,98	5,90	5,97	5,86	5,95	5,92	5,89	5,94
CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	4,41	3,90	3,40	3,69	3,57	3,94	3,85	4,18
ff-targeted editing is a significant threat for CRISPR gene editing in plant breeding	3,87	3,50	3,15	3,29	3,38	3,03	3,42	3,63
Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	3,63	3,60	2,91	3,05	3,43	3,00	3,28	3,31
CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	5,03	5,00	4,78	4,76	4,90	4,60	4,90	5,01
In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	4,79	4,90	4,92	4,75	4,67	4,92	4,83	4,88
The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	5,36	4,90	5,20	5,33	4,90	5,22	5,33	5,45
The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	5,02	4,50	4,56	4,61	4,19	4,49	4,77	4,68
CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	3,97	3,50	3,41	3,58	3,19	3,40	3,69	3,70

Discussion and conclusions

While the scientific community worked to increase the potential of CRISPR gene editing to contribute to food security and sustainability of agricultural production, the consensus on which crop(s), which trait(s) and which region(s) will benefit the most is still nebulous. Despite its potential, CRISPR has not been widely implemented as gene editing tool across agricultural industries globally due to a litany of barriers of adoption and dissemination. CRISPR gene editing in food crops, specifically staple crops, faces multiple barriers such as low consumer acceptance, regulatory issues and lack of (technical) infrastructure in different regions. The majority of existing scientific studies on CRISPR gene editing focus on small scale regions which focus on the perspectives of consumers on the technology, barriers of adoption, possible functions of the gene editing tool and what problems the technology can help to solve. Yet, no study has provided an empirical, global elicitation on the opinions of plant scientists worldwide on the subjects of barriers, functions, investments, beneficiaries and benefits for specific crops of CRISPR. This study has gathered scientific opinions across each potential region CRISPR could be deployed, both the private and public sector and over fourteen crops in order to provide an aggregated view on the major drivers, barriers and prospects of CRISPR gene editing. A better understanding of the potential of CRISPR from those on the ground floor of its evolution can help provide a better idea of its future.

Our results show that relative investments in CRISPR gene editing are envisioned to grow across all regions and both in the public and private sector over a ten-year timespan. The data emphasizes that plant scientists globally predict that CRISPR gene editing will receive a relative higher part of the total research and development budgets, across all regions and sectors. It appears that CRISPR gene editing will become a growing portion of research across the global plant science industry.

Fungus resistance and *virus resistance* were rated as the most likely functions of CRISPR gene editing to be successfully developed and implemented in agricultural production across four regions

(Africa, Asia, Europe and North America). Only African plant scientists rated *drought resistance* as a likely function to be successfully implemented using CRISPR, not surprising given the decreasing amounts of fresh water available for agricultural production across many parts of Africa. *Insect resistance* was rated as third likeliest amongst all functions, with significant higher results than the weighted mean in both Africa and Europe. *Herbicide resistance* was voted to be the highest function across rated functions in North America, which should not be surprising given the large percentage of adoption of Roundup Ready crops available currently across North America. At the sectoral level, both the public and private sectors thought *fungus resistance*, *virus resistance* and *insect resistance* were rated the most likely functions to be implemented via CRISPR. Public sector scientists expect *herbicide resistance* and *drought resistance* likely to be implemented as well, next to the aforementioned functions. Across all regions and sectors the plant scientists seem to think *fungus resistance* and *virus resistance* will likely be the most successfully implemented functions using CRISPR, with *insect resistance* as third likeliest.

Multiple barriers of adoption denoted significant higher scores than the weighted mean of the corresponding sector/region in the results. Thus, and likely most frustrating to plant scientists, *consumer perception/knowledge gap*, was thought to be the most impeding barrier of CRISPR adoption. *Policy/legal issues* scored significantly higher than the weighted mean across all regions, except for South America. This could be explained due to the fact that multiple South American countries have allowed genome edited crops to be grown, such as the production of high oleic soybeans (edited using TALEN gene editing) in Argentina (Menz et al., 2020). Europe, denoted the highest score for *policy/legal issues* out of all regions and both sectors. One potential explanation for this high score of Europe on *policy/legal issues* could be, that the European Union has the strictest regulations for CRISPR gene edited crops by making them subject to GM regulations (Purnhagen & Wesseler, 2020). *Intellectual property rights issues* denoted significant higher results than the weighted mean in Asia, Europe and North America, the regions which hold the most CRISPR patents in the market (Martin-Laffon et al., 2019). One potential explanation for this is that given the large amount of CRISPR patents, there is likely a large amount of copyright infringement or money spent on legal matters protecting that intellectual property. *High development costs* are seen as a barrier by African and South American scientists, both regions are populated with a high number of developing countries which likely are plagued by lower relative research and development budgets. Overall, across all regions the education of consumers about CRISPR and creating an understandable comprehensive regulatory framework seem to be large impediments of commercial adoption of CRISPR gene editing. In high-income countries, a clear framework for intellectual property rights of CRISPR patents is needed, whereas funding and lack of investment is an impediment in developing countries. In both the public and private sector, *consumer perceptions/knowledge gap* and *policy/legal issues* seem to be the most impeding barriers of CRISPR adoption, followed by *intellectual property rights issues*. In the private sector, scientists see *high development costs* as an issue that impedes the adoption of CRISPR adoption.

This study indicated that *maize* and *soybean* are expected to benefit the most from CRISPR gene editing across all regions, except for Oceania. *Wheat* (Asia, Europe, North America and South America), *rice* (Asia, North America and South America) and *potatoes* (Asia, Europe and North America) are other crops in which plant scientists globally see potential to benefit from the CRISPR technology. In both the public and private sector, scientists believe that *maize, soybean, wheat* and *potatoes* are most likely to benefit from CRISPR gene editing technology. The only difference between these two sectors is, that public scientists score *rice* as significantly higher than the weighted mean as well. This may not be surprising given the large role public breeding still plays in *rice* unlike *soy* and *maize.*

Little differences were found regionally on whom and what the main beneficiaries of CRISPR will be. *Reduced food insecurity* was scored significantly lower than the weighted average in Europe and North America, not surprising since neither region is plagued with high food insecurity rates. The biggest beneficiary of CRISPR adoption was estimated to be *increased yields*, for scientists in Africa, Europe and

North America. Interesting, as the yield gap is relatively small in Europe and North America (Hengsdijk & Langeveld, 2009). Little significant results were found in the public and private sector as well, where both sectors denoted high scores for *increased yields*. Also, for the public sector *producer profits* is seen as a (possible) beneficiary of CRISPR gene editing technology. The variables in this question (*reduced food insecurity*, *environmental damage in agriculture, increased nutritional value in crops, producer profits, yields and yield variability*) very much intertwine with each other in the agricultural sector, e.g. if yields increase, food insecurity is likely to decrease as well. This could be one of the potential explanations for the low number of significant results found in this question, as each variable is tested to the weighted mean.

The survey statements indicate that plant scientists are highly reluctant to the idea of CRISPR gene editing being regulated in a similar way as GM crops. Furthermore, the sector believes that CRISPR technology can be one of the most important solutions of environmental and food insecurity issues. Lastly, plant scientists indicated that the sector sees the private sector dominating the CRISPR market.

While diverse, there are some limitations to the participants of the survey itself. The first is, that the North American sample is dominated by American scientists with little representation from either Mexico or Canada. Furthermore, the Oceanian and South American sample was relatively small compared to the other four regions, with 21 and 64 respondents respectively.

Also, it is important to consider that all results of the functions, barriers, crop benefits and beneficiaries, were tested against the weighted mean of all functions/barriers/crop benefits/beneficiaries of their own region/sector. This means, that significant results only emerge when the test is significantly different from this weighted mean. This does not imply that significant lower results or results that were not different from the mean, are not of importance. The results in this study only show differences at region and sector level, whereas the situation can look different on national and local level.

Another limitation of this study is the sampling. The total amount of plant scientists per region and sector is unknown, therefore it is difficult to assess whether this study includes a representative sample for each region and sector. The results of this study are biased towards Europe and North America, as well as the public sector. Private sector plant scientists contact details are rarely publicly available and therefore this target group was more difficult to reach.

In order to better understand drivers, barriers and prospects of CRISPR at national and local level, similar research should be conducted at a more granular level. Also, at crop level it could be that major differences between the perceptions of barriers, beneficiaries and functions of CRISPR exist, for instance, maize production for livestock vs maize production for human consumption. This study can be of use for the plant science sector, policymakers and agronomists in the sense that it draws a picture on what the major perceived barriers and prospects of CRISPR are, and what differences at regional and sectoral level are. At national and local level, policymakers could test the hypotheses raised from this study to design tailored regulations and investments in the CRISPR sector. Also, plant scientists globally can use this study to see what other scientists active in different regions foresee as the most important functions, risks and implications of the technology, to seek collaboration and take the development of the technology forward.

References

Ahmad, N., Rahman, M. ur, Mukhtar, Z., Zafar, Y., & Zhang, B. (2020). A critical look on CRISPR-based genome editing in plants. *Journal of Cellular Physiology*, *235*(2), 666–682. https://doi.org/10.1002/jcp.29052

Ahmad, S., Tang, L., Shahzad, R., Mawia, A. M., Rao, G. S., Jamil, S., Wei, C., Sheng, Z., Shao, G., Wei, X., Hu, P., Mahfouz, M. M., Hu, S., & Tang, S. (2021). CRISPR-Based Crop Improvements: A Way Forward to Achieve Zero Hunger. In *Journal of Agricultural and Food Chemistry* (Vol. 69, Issue 30, pp. 8307–8323). American Chemical Society. https://doi.org/10.1021/acs.jafc.1c02653

Ali, Z., Ali, S., Tashkandi, M., Zaidi, S. S. E. A., & Mahfouz, M. M. (2016). CRISPR/Cas9-Mediated Immunity to Geminiviruses: Differential Interference and Evasion. *Scientific Reports*, *6*(May). https://doi.org/10.1038/srep26912

Andoh, C. T. (2017). Genome Editing Technologies: Ethical and Regulation Challenges for Africa. *International Journal of Health Economics and Policy*, *2*(2), 30–46. https://doi.org/10.11648/j.hep.20170202.11

Barford, E. (2013). Crop pests advancing with global warming. *Nature*. https://doi.org/10.1038/nature.2013.13644

Barrows, G., Sexton, S., & Zilberman, D. (2014). Agricultural biotechnology: The promise and prospects of genetically modified crops. *Journal of Economic Perspectives*, *28*(1), 99–120. https://doi.org/10.1257/jep.28.1.99

Bebber, D. P., Ramotowski, M. A. T., & Gurr, S. J. (2013). Crop pests and pathogens move polewards in a warming world. *Nature Climate Change*, *3*(11), 985–988. https://doi.org/10.1038/nclimate1990

Biswas, S., Zhang, D., & Shi, J. (2021a). CRISPR/Cas systems: opportunities and challenges for crop breeding. *Plant Cell Reports*, *40*(6), 979–998. https://doi.org/10.1007/s00299-021-02708-2

Biswas, S., Zhang, D., & Shi, J. (2021b). CRISPR/Cas systems: opportunities and challenges for crop breeding. In *Plant Cell Reports* (Vol. 40, Issue 6, pp. 979–998). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s00299-021-02708-2

Bodner, D. A., & Rouse, W. B. (2007). Understanding R&D value creation with organizational simulation. *Systems Engineering*, *10*(1), 64–82. https://doi.org/10.1002/sys.20064

Brookes, G., & Barfoot, P. (2020). Environmental impacts of genetically modified (GM) crop use 1996–2018: impacts on pesticide use and carbon emissions. *GM Crops and Food*, *11*(4), 215–241. https://doi.org/10.1080/21645698.2020.1773198

Cai, J., Chen, W., Huang, J., Hu, R., & Pray, C. E. (2020). The Evolving Structure of Chinese R&D Funding and its Implications for the Productivity of Agricultural Biotechnology Research. *Journal of Agricultural Economics*, *71*(2), 287–304. https://doi.org/10.1111/1477-9552.12363

Chakraborty, S., & Newton, A. C. (2011). Climate change, plant diseases and food security: An overview. In *Plant Pathology* (Vol. 60, Issue 1, pp. 2–14). https://doi.org/10.1111/j.1365-3059.2010.02411.x

Chaloner, T. M., Gurr, S. J., & Bebber, D. P. (2021). Plant pathogen infection risk tracks global crop yields under climate change. *Nature Climate Change*, *11*(8), 710–715. https://doi.org/10.1038/s41558-021-01104-8

Charles, H., Godfray, J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (n.d.). *Food Security: The Challenge of Feeding 9 Billion People*. https://www.science.org

Chilcoat, D., Liu, Z. Bin, & Sander, J. (2017). Use of CRISPR/Cas9 for Crop Improvement in Maize and Soybean. In *Progress in Molecular Biology and Translational Science* (1st ed., Vol. 149). Elsevier Inc. https://doi.org/10.1016/bs.pmbts.2017.04.005

Cui, K., & Shoemaker, S. P. (2018). Public perception of genetically-modified (GM) food: A nationwide Chinese consumer study. *Npj Science of Food*, *2*(1), 3–12. https://doi.org/10.1038/s41538-018-0018-4

Ding, Y., Li, H., Chen, L. L., & Xie, K. (2016). Recent advances in genome editing using CRISPR/Cas9. *Frontiers in Plant Science*, *7*(MAY2016), 1–12. https://doi.org/10.3389/fpls.2016.00703

Dolan, F., Lamontagne, J., Link, R., Hejazi, M., Reed, P., & Edmonds, J. (2021). Evaluating the economic impact of water scarcity in a changing world. *Nature Communications*, *12*(1). https://doi.org/10.1038/s41467-021-22194-0

Dolezel, M., Lüthi, C., & Gaugitsch, H. (2020). Beyond limits – the pitfalls of global gene drives for environmental risk assessment in the european union. *BioRisk*, *15*, 1–29. https://doi.org/10.3897/biorisk.15.49297

Enfissi, E. M. A., Drapal, M., Perez-Fons, L., Nogueira, M., Berry, H. M., Almeida, J., & Fraser, P. D. (2021). New plant breeding techniques and their regulatory implications: An opportunity to advance metabolomics approaches. In *Journal of Plant Physiology* (Vols. 258–259). Elsevier GmbH. https://doi.org/10.1016/j.jplph.2021.153378

Evenson, R. E., & Gollin, D. (2003). *Assessing the Impact of the Green Revolution , 1960 to 2000*. *300*(May), 758–763.

Falkenmark, M. (2013). Growing water scarcity in agriculture: Future challenge to global water security. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *371*(2002). https://doi.org/10.1098/rsta.2012.0410

FAO. (2011). *Frequently Asked Questions about FAO and Agricultural Biotechnology*. https://www.fao.org/fileadmin/user_upload/biotech/docs/faqsen.pdf

FAO. (2012). *Coping with water scarcity : an action framework for agriculture and food security*. Food and Agriculture Organization of the United Nations.

FAO. (2019). *FAOSTAT. Crops and Livestock products World Production Quantity Crops Primary 2019. Latest Update: 15/09/2021. Date accessed: 30/09/2021. http://www.fao.org/faostat/en/#data/QCL*. FAO.

FAO. (2020). *The state of food security and nutrition in the world*. http://www.fao.org/3/ca9692en/ca9692en.pdf

FAO. (2021). *The state of food security and nutrition in the world 2021 - Transforming food systems for food security, immmproved nutrition and affordable healthy diets for all*. http://www.fao.org/3/cb4474en/cb4474en.pdf

Farhat, S., Jain, N., Singh, N., Sreevathsa, R., Dash, P. K., Rai, R., Yadav, S., Kumar, P., Sarkar, A. K., Jain, A., Singh, N. K., & Rai, V. (2019). CRISPR-Cas9 directed genome engineering for enhancing salt stress tolerance in rice. In *Seminars in Cell and Developmental Biology* (Vol. 96, pp. 91–99). Elsevier Ltd. https://doi.org/10.1016/j.semcdb.2019.05.003

Fuglie, K. (2016). The growing role of the private sector in agricultural research and development world-wide. *Global Food Security*, *10*(September 2016), 29–38. https://doi.org/10.1016/j.gfs.2016.07.005

Georges, F., & Ray, H. (2017a). Genome editing of crops: A renewed opportunity for food security. *GM Crops and Food*, *8*(1), 1–12. https://doi.org/10.1080/21645698.2016.1270489

Georges, F., & Ray, H. (2017b). Genome editing of crops: A renewed opportunity for food security. In *GM Crops and Food* (Vol. 8, Issue 1, pp. 1–12). Taylor and Francis Ltd. https://doi.org/10.1080/21645698.2016.1270489

Graham, N., Patil, G. B., Bubeck, D. M., Dobert, R. C., Glenn, K. C., Gutsche, A. T., Kumar, S., Lindbo, J. A., Maas, L., May, G. D., Vega-Sanchez, M. E., Stupar, R. M., & Morrell, P. L. (2020). Plant genome editing and the relevance of off-target changes1[OPEN]. *Plant Physiology*, *183*(4), 1453–1471. https://doi.org/10.1104/pp.19.01194

Hasegawa, T., Sakurai, G., Fujimori, S., Takahashi, K., Hijioka, Y., & Masui, T. (2021). Extreme climate events increase risk of global food insecurity and adaptation needs. *Nature Food*, *2*(8), 587–595. https://doi.org/10.1038/s43016-021-00335-4

Hengsdijk, H., & Langeveld, J. W. A. (2009). *Yield trends and yield gap analysis of major crops in the world*.

IPCC. (2021). *Assessment Report 6 Climate Change 2021: The Physical Science Basis*. https://www.ipcc.ch/report/ar6/wg1/

Ishii, T., & Araki, M. (2016). Consumer acceptance of food crops developed by genome editing. *Plant Cell Reports*, *35*(7), 1507–1518. https://doi.org/10.1007/s00299-016-1974-2

Jia, H., & Nian, W. (2014). Targeted genome editing of sweet orange using Cas9/sgRNA. *PLoS ONE*, *9*(4). https://doi.org/10.1371/journal.pone.0093806

Jiang, F., & Doudna, J. A. (2017). CRISPR – Cas9 Structures and Mechanisms. *Advance*, *46*, 505–531. https://doi.org/https://doi.org/10.1146/annurev-biophys-062215-010822

John, D. A., & Babu, G. R. (2021). Lessons From the Aftermaths of Green Revolution on Food System and Health. In *Frontiers in Sustainable Food Systems* (Vol. 5). Frontiers Media S.A. https://doi.org/10.3389/fsufs.2021.644559

Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert Scale: Explored and Explained. *British Journal of Applied Science & Technology*, *7*(4), 396–403. https://doi.org/10.9734/bjast/2015/14975

Joshi, R. K., Bharat, S. S., & Mishra, R. (2020). Engineering drought tolerance in plants through CRISPR/Cas genome editing. *3 Biotech*, *10*(9), 1–14. https://doi.org/10.1007/s13205-020-02390-3

Joung, J. K., & Sander, J. D. (2013). TALENs: A widely applicable technology for targeted genome editing. *Nature Reviews Molecular Cell Biology*, *14*(1), 49–55. https://doi.org/10.1038/nrm3486

Kaminski, R., Chen, Y., Fischer, T., Tedaldi, E., Napoli, A., Zhang, Y., Karn, J., Hu, W., & Khalili, K. (2016). Elimination of HIV-1 Genomes from Human T-lymphoid Cells by CRISPR/Cas9 Gene Editing. *Scientific Reports*, *6*(December 2015), 1–15. https://doi.org/10.1038/srep22555

Karavolias, N. G., Horner, W., Abugu, M. N., & Evanega, S. N. (2021). Application of Gene Editing for Climate Change in Agriculture. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.685801

Karpicka-Ignatowska, K., Laska, A., Rector, B. G., Skoracka, A., & Kuczyński, L. (2021). Temperature-dependent development and survival of an invasive genotype of wheat curl mite, Aceria tosichella.

Experimental and Applied Acarology, *83*(4), 513–525. https://doi.org/10.1007/s10493-021-00602-w

Klümper, W., & Qaim, M. (2014). A meta-analysis of the impacts of genetically modified crops. *PLoS ONE*, *9*(11). https://doi.org/10.1371/journal.pone.0111629

Kumar, K., Gambhir, G., Dass, A., Tripathi, A. K., Singh, A., Jha, A. K., Yadava, P., Choudhary, M., & Rakshit, S. (2020). Genetically modified crops: current status and future prospects. In *Planta* (Vol. 251, Issue 4). Springer. https://doi.org/10.1007/s00425-020-03372-8

Leighton, K., Kardong-Edgren, S., Schneidereith, T., & Foisy-Doll, C. (2021). Using Social Media and Snowball Sampling as an Alternative Recruitment Strategy for Research. *Clinical Simulation in Nursing*, *55*, 37–42. https://doi.org/10.1016/j.ecns.2021.03.006

Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature*, *529*(7584), 84–87. https://doi.org/10.1038/nature16467

Li, W., Teng, F., Li, T., Zhou, Q., Ding, Y., Li, H., Chen, L. L., Xie, K., Zhang, K., Raboanatahiry, N., Zhu, B., Li, M., Oude Blenke, E., Evers, M. J. W., Mastrobattista, E., & van der Oost, J. (2016). CRISPR-Cas9 gene editing: Delivery aspects and therapeutic potential. *Frontiers in Plant Science*, *31*(February), 684–686. https://doi.org/10.1016/j.jconrel.2016.08.002

Ma, C. Sen, Zhang, W., Peng, Y., Zhao, F., Chang, X. Q., Xing, K., Zhu, L., Ma, G., Yang, H. P., & Rudolf, V. H. W. (2021). Climate warming promotes pesticide resistance through expanding overwintering range of a global pest. *Nature Communications*, *12*(1). https://doi.org/10.1038/s41467-021-25505-7

Manghwar, H., Lindsey, K., Zhang, X., & Jin, S. (2019). CRISPR/Cas System: Recent Advances and Future Prospects for Genome Editing. *Trends in Plant Science*, *24*(12), 1102–1125. https://doi.org/10.1016/j.tplants.2019.09.006

Martin-Laffon, J., Kuntz, M., & Ricroch, A. E. (2019). Worldwide CRISPR patent landscape shows strong geographical biases. *Nature Biotechnology*, *37*(6), 613–620. https://doi.org/10.1038/s41587-019-0138-7

Martin-Laffon, J., Kuntz, M., Ricroch, A. E., Church, G. M., Brokowski, C., Adli, M., Schroeder, D., Cook, J., Hirsch, F., Fenet, S., Custers, R., Casacuberta, J. M., Eriksson, D., Sági, L., Schiemann, J., Zhang, X. H., Tee, L. Y., Wang, X. G., Huang, Q. S., … European Commission. (2020). Epistemological depth in a GM crops controversy. *Frontiers in Plant Science*, *37*(1), 1–12. https://doi.org/10.1186/s13059-020-02204-y

Masmitjà, M. P., Knödlseder, N., & Güell, M. (2019). CRISPR-gRNA Design. In *Methods in Molecular Biology* (Vol. 1961, pp. 3–11). Humana Press, New York, NY. https://doi.org/10.1007/978-1-4939-9170-9_14

Massel, K., Lam, Y., Wong, A. C. S., Hickey, L. T., Borrell, A. K., & Godwin, I. D. (2021a). Hotter, drier, CRISPR: the latest edit on climate change. *Theoretical and Applied Genetics*, *0123456789*. https://doi.org/10.1007/s00122-020-03764-0

Massel, K., Lam, Y., Wong, A. C. S., Hickey, L. T., Borrell, A. K., & Godwin, I. D. (2021b). Hotter, drier, CRISPR: the latest edit on climate change. In *Theoretical and Applied Genetics* (Vol. 134, Issue 6, pp. 1691–1709). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s00122-020-03764-0

Menz, J., Modrzejewski, D., Hartung, F., Wilhelm, R., & Sprink, T. (2020). Genome Edited Crops Touch the Market: A View on the Global Development and Regulatory Environment. *Frontiers in Plant Science*, *11*(October), 1–17. https://doi.org/10.3389/fpls.2020.586027

Müller, C., Cramer, W., Hare, W. L., & Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(11), 4313–4315. https://doi.org/10.1073/pnas.1015078108

Mulvihill, J. J., Capps, B., Joly, Y., Lysaght, T., Zwart, H. A. E., & Chadwick, R. (2017). Ethical issues of CRISPR technology and gene editing through the lens of solidarity. *British Medical Bulletin*, *122*(1), 17–29. https://doi.org/10.1093/bmb/ldx002

Nature Food. (2020). Public–private roles beyond crop yields. *Nature Food*, *1*(6), 311. https://doi.org/10.1038/s43016-020-0109-7

Noble, C., Olejarz, J., Esvelt, K. M., Church, G. M., & Nowak, M. A. (2017). Evolutionary dynamics of CRISPR gene drives. *Science Advances*, *3*(4), 3–10. https://doi.org/10.1126/sciadv.1601964

Pingali, P. L. (1994). *Confronting the environmental consequences of the Green Revolution in Asia Strategic Forsight (ISPC): Global Food Systems-Threats and opportunities View project*. https://www.researchgate.net/publication/5056026

Pingali, P. L. (2012). *Green Revolution: Impacts, limits, and the path ahead*. *109*(31), 12302–12308. https://doi.org/10.1073/pnas.0912953109

Purnhagen, K. (2018). *European Court: "CRISPR Cas and other new plant breeding techniques are GMO."* Wageningen University & Research. https://www.wur.nl/en/newsarticle/European-Court-CRISPR-Cas-and-other-new-plant-breeding-techniques-are-GMO.htm

Purnhagen, K., & Wesseler, J. (2020). EU Regulation of New Plant Breeding Technologies and Their Possible Economic Implications for the EU and Beyond. *Applied Economic Perspectives and Policy*. https://doi.org/10.1002/aepp.13084

Qaim, M. (2016). *GENETICALLY M ODIFIED CROPS AND AGRICULTURAL DEVELOPMENT* (1st ed.).

Qaim, M. (2019). Role of New Plant Breeding Technologies for Food Security and Sustainable Agricultural Development. *Applied Economic Perspectives and Policy*, *42*(2), 129–150. https://doi.org/10.1002/aepp.13044

Qaim, M. (2020). Role of New Plant Breeding Technologies for Food Security and Sustainable Agricultural Development. *Applied Economic Perspectives and Policy*, *42*(2), 129–150. https://doi.org/10.1002/aepp.13044

Raman, R. (2017). The impact of Genetically Modified (GM) crops in modern agriculture: A review. In *GM Crops and Food* (Vol. 8, Issue 4, pp. 195–208). Taylor and Francis Ltd. https://doi.org/10.1080/21645698.2017.1413522

Ray, D. K., Mueller, N. D., West, P. C., & Foley, J. A. (2013). Yield Trends Are Insufficient to Double Global Crop Production by 2050. *PLoS ONE*, *8*(6). https://doi.org/10.1371/journal.pone.0066428

Ray, D. K., West, P. C., Clark, M., Gerber, J. S., Prishchepov, A. V., & Chatterjee, S. (2019). Climate change has likely already affected global food production. *PLoS ONE*, *14*(5). https://doi.org/10.1371/journal.pone.0217148

Ricroch, A. (2019). Global developments of genome editing in agriculture. *Transgenic Research*, *28*, 45–52. https://doi.org/10.1007/s11248-019-00133-6

Ricroch, A., Clairand, P., & Harwood, W. (2017). Use of CRISPR systems in plant genome editing: toward new opportunities in agriculture. *Emerging Topics in Life Sciences*, *1*(2), 169–182. https://doi.org/10.1042/etls20170085

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., & Jones, J. W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3268–3273. https://doi.org/10.1073/pnas.1222463110

Sandelowski, M. (2000). Focus on research methods: Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. *Research in Nursing and Health*, *23*(3), 246–255. https://doi.org/10.1002/1098-240x(200006)23:3<246::aid-nur9>3.0.co;2-h

Schaart, J., Riemens, M., Van de Wiel, C., Lotz, B., & Smulders, R. (2015). *Opportunities of New Plant Breeding Techniques Opportunities of new plant breeding techniques | 1 Content*. https://edepot.wur.nl/357723

Shan-e-Ali Zaidi, S., Vanderschuren, H., Qaim, M., Mahfouz, M. M., Kohli, A., Mansoor, S., & Tester, M. (2019). New plant breeding technologies for food security. In *Science* (Vol. 363, Issue 6434, pp. 1390–1391). American Association for the Advancement of Science. https://doi.org/10.1126/science.aav6316

Shew, A. M., Nalley, L. L., Snell, H. A., Nayga, R. M., & Dixon, B. L. (2018). CRISPR versus GMOs: Public acceptance and valuation. *Global Food Security*, *19*(September), 71–80. https://doi.org/10.1016/j.gfs.2018.10.005

Smith, V., Wesseler, J. H. H., & Zilberman, D. (2021). New plant breeding technologies: An assessment of the political economy of the regulatory environment and implications for sustainability. *Sustainability (Switzerland)*, *13*(7). https://doi.org/10.3390/su13073687

Smyth, S. J., McDonald, J., & Falck-Zepeda, J. (2014). Investment, regulation, and uncertainty: managing new plant breeding techniques. *GM Crops & Food*, *5*(1), 44–57. https://doi.org/10.4161/gmcr.27465

Song, G., Jia, M., Chen, K., Kong, X., Khattak, B., Xie, C., Li, A., & Mao, L. (2016). CRISPR/Cas9: A powerful tool for crop genome editing. *Crop Journal*, *4*(2), 75–82. https://doi.org/10.1016/j.cj.2015.12.002

Song, M., Kim, Y. H., Kim, J. S., & Kim, H. (2014). Genome engineering in human cells. In *Methods in Enzymology* (1st ed., Vol. 546, Issue C). Elsevier Inc. https://doi.org/10.1016/B978-0-12-801185-0.00005-2

Taherdoost, H. (2019). What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale. In *International Journal of Academic Research in Management (IJARM)* (Vol. 8, Issue 1).

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(50), 20260–20264. https://doi.org/10.1073/pnas.1116437108

Tiwari, J. K., Buckseth, T., Singh, R. K., Kumar, M., & Kant, S. (2020a). Prospects of Improving Nitrogen Use Efficiency in Potato: Lessons From Transgenics to Genome Editing Strategies in Plants. *Frontiers in Plant Science*, *11*(December), 1–6. https://doi.org/10.3389/fpls.2020.597481

Tiwari, J. K., Buckseth, T., Singh, R. K., Kumar, M., & Kant, S. (2020b). Prospects of Improving Nitrogen Use Efficiency in Potato: Lessons From Transgenics to Genome Editing Strategies in Plants.

Frontiers in Plant Science, *11*. https://doi.org/10.3389/fpls.2020.597481

Tripp, R., & Byerlee, D. (2000). PUBLIC PLANT BREEDING IN AN ERA OF PRIVATISATION. *Natural Resource Perspectives*, 1–4.

United Nations - Department of Economic and Social Affairs. (2019). World population prospects 2019 - Highlights. In *Department of Economic and Social Affairs. World Population Prospects 2019.*

Uzogara, S. G. (2000). The impact of genetic modification of human foods in the 21st century: A review. In *Biotechnology Advances* (Vol. 18). www.betterfoods.org

Van de Wiel, C., Schaart, J., Prins, T., Smulders, R., & Lotz, bert. (2018). *Plant breeding techniques in a new era*. https://edepot.wur.nl/447321

Van der Oost, J., & Fresco, L. O. (2021). Waive CRISPR patents to meet food needs in low-income countries. *Nature*, *15*(15).

van Dijk, M., Morley, T., Rau, M. L., & Saghai, Y. (2021). A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nature Food*, *2*(7), 494–501. https://doi.org/10.1038/s43016-021-00322-9

Verschuur, J., Li, S., Wolski, P., & Otto, F. E. L. (2021). Climate change as a driver of food insecurity in the 2007 Lesotho-South Africa drought. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-83375-x

Wang, F., Wang, C., Liu, P., Lei, C., Hao, W., Gao, Y., Liu, Y. G., & Zhao, K. (2016). Enhanced rice blast resistance by CRISPR/ Cas9-Targeted mutagenesis of the ERF transcription factor gene OsERF922. *PLoS ONE*, *11*(4), 1–18. https://doi.org/10.1371/journal.pone.0154027

Wilson, L. O. W., O'Brien, A. R., & Bauer, D. C. (2018). The current state and future of CRISPR-Cas9 gRNA design tools. *Frontiers in Pharmacology*, *9*(JUN), 1–6. https://doi.org/10.3389/fphar.2018.00749

Yu, Q. H., Wang, B., Li, N., Tang, Y., Yang, S., Yang, T., Xu, J., Guo, C., Yan, P., Wang, Q., & Asmutola, P. (2017). CRISPR/Cas9-induced Targeted Mutagenesis and Gene Replacement to Generate Long-shelf Life Tomato Lines. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-12262-1

Zahoor, M. K., Ahmad, A., Zahoor, M. A., Majeed, H. N., Zulhussnain, M., & Ranian, K. (2021). CRISPR/Cas based Insect Resistance in Crops. In *CRISPR Crops* (pp. 117–149). Springe, Singapore. https://doi.org/10.1007/978-981-15-7142-8

Zhang, F., Wen, Y., & Guo, X. (2014). CRISPR/Cas9 for genome editing: Progress, implications and challenges. *Human Molecular Genetics*, *23*(R1), 40–46. https://doi.org/10.1093/hmg/ddu125

Zhang, K., Raboanatahiry, N., Zhu, B., & Li, M. (2017). Progress in genome editing technology and its application in plants. *Frontiers in Plant Science*, *8*(February). https://doi.org/10.3389/fpls.2017.00177

Zhang, X. H., Tee, L. Y., Wang, X. G., Huang, Q. S., & Yang, S. H. (2015). Off-target effects in CRISPR/Cas9-mediated genome engineering. *Molecular Therapy - Nucleic Acids*, *4*(11), e264. https://doi.org/10.1038/mtna.2015.37

Zhang, Y., Malzahn, A. A., Sretenovic, S., & Qi, Y. (2019). The emerging and uncultivated potential of CRISPR technology in plant science. In *Nature Plants* (Vol. 5, Issue 8, pp. 778–794). Palgrave Macmillan Ltd. https://doi.org/10.1038/s41477-019-0461-5

Zhu, H., Li, C., & Gao, C. (2020). Applications of CRISPR–Cas in agriculture and plant biotechnology. *Nature Reviews Molecular Cell Biology*, *21*(11), 661–677. https://doi.org/10.1038/s41580-020-

00288-9

Zilberman, D., Holland, T. G., & Trilnick, I. (2018). Agricultural GMOs-What we know and where scientists disagree. In *Sustainability (Switzerland)* (Vol. 10, Issue 5). MDPI AG. https://doi.org/10.3390/su10051514

Zilberman, D., Kaplan, S., & Wesseler, J. H. H. (2015). *The Loss from Underutilizing GM technologies*. https://www.researchgate.net/publication/297355631

Appendices

Appendix A: Export Survey CRISPR gene editing Drivers, Barriers & Prospects

CRISPR Drivers, Barriers & Prospects – A comparative study among US, EU and African plant scientists
Start of Block: Introduction block
Q32 Thank you for your participation!
In this study we are interested in your perceptions about the drivers, barriers and prospects of the CRISPR gene editing technology, with a focus on the technology´s potential for the production of food crops. Your opinion is important to us and we hope that you will take the time to give us your insights.

Risks and Benefits: Your participation will assist in the advancement of CRISPR gene editing technology and give insights in the drivers, barriers and prospects among plant scientists in Europe, Africa and North America concerning the technology. There are no anticipated risks to participating in this study.

There is no compensation for your time, which we estimate will take approximately **5 minutes**.

Voluntary Participation: Your participation in the research is completely voluntary.

Confidentiality: Your responses on the survey will be recorded anonymously. Only basic demographic information (i.e. age, gender, education etc.) will be collected.

Right to Withdraw: You are free to refuse to participate in the research and to stop participation during the survey if you choose.

If you have questions or concerns about this study, you may contact llnalley@uark.edu. For questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University's Compliance Coordinator, at 1+ (479) 575-2208 or by e-mail at irb@uark.edu.

Q31 I am over the age of 18 and I would like to participate in this research

○ Yes (1)

○ No (2)

Skip To: End of Survey If Q31 = No

Q58 By continuing and completing this survey, I am agreeing for my anonymous responses to be used in this research.

○ Continue (1)

○ Do not continue (2)

Skip To: End of Survey If Q58 = Do not continue

Page Break

Q41 Please indicate your academic level:

○ High school (4)

○ Bachelor of Science (1)

○ Master of Science (2)

- ◯ Doctor of Philosophy (Ph.D). (7)
- ◯ Postdoctoral Researcher (3)
- ◯ Professorship (6)
- ◯ Other (If yes, please specify) (5) ____

Q27 Are you active in the public or private plant science sector?

- ◯ Public (1)
- ◯ Private (2)
- ◯ Both (please specify in the next question) (3)
- ◯ I am not active in the plant science sector (4)

Skip To: End of Survey If Q27 = I am not active in the plant science sector

Display This Question:
If Q27 = Both (please specify in the next question)

Q1 Please indicate how much of your time (in %) you are active in the public and/or private plant science sector:

	Public sector % Private sector 0 10 20 30 40 50 60 70 80 90 100
Distribution public/private sector ()	

Q2 How many years of experience do you have in the plant science sector?

- ◯ 0-10 years (4)
- ◯ 10-20 years (5)
- ◯ 20-30 years (6)
- ◯ 30-40 years (7)
- ◯ 40+ years (8)

Q56 Please indicate how much of your time (in %) you are active in the fundamental and/or applied plant sciences:

	Fundamental plant sciences % Applied plant sciences
	0 10 20 30 40 50 60 70 80 90 100
Distribution fundamental/applied plant sciences ()	

Q55
The focus in my role as plant scientist is mainly on (please specify using the sliders, in %, adding to a total of 100%):

	% %
	0 10 20 30 40 50 60 70 80 90 100
Yield improvement ()	
Stress resilience (biotic/abiotic) ()	
Nutritional alteration/improvement ()	
Mineral uptake (e.g. fertilizer efficiency) ()	
Storage (e.g. shelf life) ()	
Other (please specify) ()	

Page Break

Q25 Which crops are you primarily working in?

- ▢ Wheat (1)
- ▢ Maize (2)

- ☐ Soybean (3)
- ☐ Rice (4)
- ☐ Potatoes (5)
- ☐ Cassava (7)
- ☐ Sorghum (8)
- ☐ Millet (9)
- ☐ Yams (10)
- ☐ Plantains (11)
- ☐ Vegetables (if yes, please specify) (15) ____
- ☐ Fruits (if yes, please specify) (16) ____
- ☐ Legumes (if yes, please specify) (17) ____
- ☐ Other (if yes, please specify) (6) ____

Q4 Which regions are of primary focus concerning the R&D activities of your research group/department?
Note: please indicate in which countries the ***department you work in*** *is actively conducting R&D*

- ☐ Africa (1)
- ☐ Asia (2)
- ☐ Europe (3)
- ☐ Oceania (5)
- ☐ North America (4)
- ☐ South America (6)

Page Break

End of Block: Introduction block

Start of Block: CRISPR gene editing activity & budgets

Q13 Is your research group/department active in CRISPR gene editing Research & Development?

- ○ Yes (1)
- ○ No (2)

Display This Question:
If Q13 = Yes

Q5 When did your research group/department start their CRISPR gene editing Research & Development?
Note: Starting in this context means, R&D budget was allocated for the first time to explore the potential of the CRISPR gene editing technology.

- ○ Before 2013 (13)
- ○ 2013 (4)
- ○ 2014 (5)
- ○ 2015 (6)
- ○ 2016 (7)
- ○ 2017 (8)
- ○ 2018 (9)
- ○ 2019 (10)
- ○ 2020 (11)
- ○ 2021 (12)

Display This Question:
If Q13 = Yes

Q6 Could you indicate for your research group/department, what percentage of the total R&D budget is **currently** allocated to CRISPR gene editing Research & Development?

	%	%	Not Applicable
	0 10 20 30 40 50 60 70 80 90 100		
% of R&D budget currently allocated to CRISPR gene editing ()			

Q7 Could you indicate for your research group/department, what percentage of the total R&D budget do you envision **will be** allocated to CRISPR gene editing Research & Development in 3, 5 and 10 years?

	%	%	Not Applicable
	0 10 20 30 40 50 60 70 80 90 100		
in 3 years ()			
in 5 years ()			
in 10 years ()			

Page Break

End of Block: CRISPR gene editing activity & budgets

Start of Block: Applications & Barriers
Display This Question:
If Q4 = Africa

Q23 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **Africa**? Rate each on a scale from 1 to 7.

Note: 53ultinatio development and implementation in this context means that the corresponding function can 53ultinationa be developed for, and applied to multiple crops grown in the region.

	1 (Low probability) (85)	2 (86)	3 (87)	4 (Medium probability) (88)	5 (89)	6 (90)	7 (High probability) (91)	8 I don´t know (92)
Herbicide resistance (1)	○	○	○	○	○	○	○	○
Drought resistance (2)	○	○	○	○	○	○	○	○
Salt soil resistance (3)	○	○	○	○	○	○	○	○

Insect resistance (4)								
Biofortification (5)								
Fungus resistance (6)								
Viruses resistance (7)								
Increased shelf life (9)								
Fertilizer use efficiency (10)								
Improved cultivation (11)								
Other (if yes, please specify) (8)								

Display This Question:
If Q4 = Asia

Q39 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **Asia**? Rate each on a scale from 1 to 7.

Note: 54ultinatio development and implementation in this context means that the corresponding function can 54ultinationa be developed for and applied to multiple crops grown in the region.

	1 (Low probability) (23)	2 (24)	3 (25)	4 (Medium probability) (26)	5 (27)	6 (28)	7 (High probability) (29)	8 I don´t know (30)
Herbicide resistance (1)								
Drought resistance (2)								
Salt soil resistance (3)								
Insect resistance (4)								
Biofortification (5)								
Fungus resistance (6)								
Viruses resistance (7)								

Increased shelf life (9)								
Fertilizer use efficiency (10)								
Improved cultivation (11)								
Other (if yes, please specify) (8)								

Display This Question:
If Q4 = Europe

Q38 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **Europe**? Rate each on a scale from 1 to 7.

Note: 55ultinatio development and implementation in this context means that the corresponding function can 55ultinationa be developed for and applied to multiple crops grown in the region.

	1 (Low probability) (30)	2 (31)	3 (32)	4 (Medium probability) (33)	5 (34)	6 (35)	7 (High probability) (36)	8 I don´t know (37)
Herbicide resistance (1)								
Drought resistance (2)								
Salt soil resistance (3)								
Insect resistance (4)								
Biofortification (5)								
Fungus resistance (6)								
Viruses resistance (7)								
Increased shelf life (9)								
Fertilizer use efficiency (10)								
Improved cultivation (11)								

Other (if yes, please specify) (8)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = Oceania

Q37 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **Oceania**? Rate each on a scale from 1 to 7.

Note: 56ultinatio development and implementation in this context means that the corresponding function can 56ultinationa be developed for and applied to multiple crops grown in the region.

	1 (Low probability) (23)	2 (24)	3 (25)	4 (Medium probability) (26)	5 (27)	6 (28)	7 (High probability) (29)	8 I don´t know (30)
Herbicide resistance (1)	○	○	○	○	○	○	○	○
Drought resistance (2)	○	○	○	○	○	○	○	○
Salt soil resistance (3)	○	○	○	○	○	○	○	○
Insect resistance (4)	○	○	○	○	○	○	○	○
Biofortification (5)	○	○	○	○	○	○	○	○
Fungus resistance (6)	○	○	○	○	○	○	○	○
Viruses resistance (7)	○	○	○	○	○	○	○	○
Increased shelf life (9)	○	○	○	○	○	○	○	○
Fertilizer use efficiency (10)	○	○	○	○	○	○	○	○
Improved cultivation (11)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (8)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = North America

Q36 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **North America**? Rate each on a scale from 1 to 7.

Note: 57ultinatio development and implementation in this context means that the corresponding function can 57ultinationa be developed for and applied to multiple crops grown in the region.

	1 (Low probability) (23)	2 (24)	3 (25)	4 (Medium probability) (26)	5 (27)	6 (28)	7 (High probability) (29)	8 I don´t know (30)
Herbicide resistance (1)	○	○	○	○	○	○	○	○
Drought resistance (2)	○	○	○	○	○	○	○	○
Salt soil resistance (3)	○	○	○	○	○	○	○	○
Insect resistance (4)	○	○	○	○	○	○	○	○
Biofortification (5)	○	○	○	○	○	○	○	○
Fungus resistance (6)	○	○	○	○	○	○	○	○
Viruses resistance (7)	○	○	○	○	○	○	○	○
Increased shelf life (9)	○	○	○	○	○	○	○	○
Fertilizer use efficiency (10)	○	○	○	○	○	○	○	○
Improved cultivation (11)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (8)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = South America

Q35 Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in **South America**? Rate each on a scale from 1 to 7.

Note: 57ultinatio development and implementation in this context means that the corresponding function can 57ultinationa be developed for and applied to multiple crops grown in the region.

	1 (Low probability) (37)	2 (38)	3 (39)	4 (Medium probability) (40)	5 (41)	6 (42)	7 (High probability) (43)	8 I don´t know (44)

Herbicide resistance (1)	○	○	○	○	○	○	○	○
Drought resistance (2)	○	○	○	○	○	○	○	○
Salt soil resistance (3)	○	○	○	○	○	○	○	○
Insect resistance (4)	○	○	○	○	○	○	○	○
Biofortification (5)	○	○	○	○	○	○	○	○
Fungus resistance (6)	○	○	○	○	○	○	○	○
Viruses resistance (7)	○	○	○	○	○	○	○	○
Increased shelf life (9)	○	○	○	○	○	○	○	○
Fertilizer use efficiency (10)	○	○	○	○	○	○	○	○
Improved cultivation (11)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (8)	○	○	○	○	○	○	○	○

Page Break

Display This Question:
If Q4 = Africa

Q14 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **Africa:**

	Strongly agree (49)	Agree (50)	Somewhat agree (51)	Neither agree nor disagree (52)	Somewhat disagree (53)	Disagree (54)	Strongly disagree (55)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Africa (1)	○	○	○	○	○	○	○
Struggling to find competent **delivery methods** are a	○	○	○	○	○	○	○

major barrier for CRISPR gene editing implementation in Africa (2)							
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in Africa (3)	○	○	○	○	○	○	○
Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Africa (4)	○	○	○	○	○	○	○
Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Africa (5)	○	○	○	○	○	○	○
Off-target effects are a major barrier for CRISPR gene editing implementation in Africa (6)	○	○	○	○	○	○	○
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Africa (7)	○	○	○	○	○	○	○
High development and implementation costs are a major barrier for CRISPR gene editing implementation in Africa (10)	○	○	○	○	○	○	○

The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Africa (11)	◯	◯	◯	◯	◯	◯	◯

Display This Question:
If Q4 = Asia

Q43 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **Asia:**

	Strongly agree (13)	Agree (14)	Somewhat agree (15)	Neither agree nor disagree (16)	Somewhat disagree (17)	Disagree (18)	Strongly disagree (19)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Asia (1)	◯	◯	◯	◯	◯	◯	◯
Struggling to find competent **delivery methods** are a major barrier for CRISPR gene editing implementation in Asia (2)	◯	◯	◯	◯	◯	◯	◯
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in Asia (3)	◯	◯	◯	◯	◯	◯	◯
Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Asia (4)	◯	◯	◯	◯	◯	◯	◯
Consumer perceptions and lack of knowledge on CRISPR gene gene edited foods	◯	◯	◯	◯	◯	◯	◯

are a major barrier for CRISPR gene editing implementation in Asia (5)							
Off-target effects are a major barrier for CRISPR gene editing implementation in Asia (6)							
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Asia (7)							
High development and implementation costs are a major barrier for CRISPR gene editing implementation in Asia (10)							
The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Asia (11)							

Display This Question:
If Q4 = Europe

Q44 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **Europe:**

	Strongly agree (13)	Agree (14)	Somewhat agree (15)	Neither agree nor disagree (16)	Somewhat disagree (17)	Disagree (18)	Strongly disagree (19)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Europe (1)							

Struggling to find competent **delivery methods** are a major barrier for CRISPR gene editing implementation in Europe (2)	○	○	○	○	○	○	○
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in Europe (3)	○	○	○	○	○	○	○
Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Europe (4)	○	○	○	○	○	○	○
Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Europe (5)	○	○	○	○	○	○	○
Off-target effects are a major barrier for CRISPR gene editing implementation in Europe (6)	○	○	○	○	○	○	○
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Europe (7)	○	○	○	○	○	○	○
High development and implementation costs are a major barrier for CRISPR	○	○	○	○	○	○	○

gene editing implementation in Europe (10)							
The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Europe (11)	◯	◯	◯	◯	◯	◯	◯

Display This Question:
If Q4 = Oceania

Q45 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **Oceania:**

	Strongly agree (13)	Agree (14)	Somewhat agree (15)	Neither agree nor disagree (16)	Somewhat disagree (17)	Disagree (18)	Strongly disagree (19)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Oceania (1)	◯	◯	◯	◯	◯	◯	◯
Struggling to find competent **delivery methods** are a major barrier for CRISPR gene editing implementation in Oceania (2)	◯	◯	◯	◯	◯	◯	◯
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in Oceania (3)	◯	◯	◯	◯	◯	◯	◯
Intellectual property rights issues are a major	◯	◯	◯	◯	◯	◯	◯

barrier for CRISPR gene editing implementation in Oceania (4)							
Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Oceania (5)	○	○	○	○	○	○	○
Off-target effects are a major barrier for CRISPR gene editing implementation in Oceania (6)	○	○	○	○	○	○	○
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Oceania (7)	○	○	○	○	○	○	○
High development and implementation costs are a major barrier for CRISPR gene editing implementation in Oceania (10)	○	○	○	○	○	○	○
The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Oceania (11)	○	○	○	○	○	○	○

Display This Question:
If Q4 = North America

Q46 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **North America:**

	Strongly agree (13)	Agree (14)	Somewhat agree (15)	Neither agree nor disagree (16)	Somewhat disagree (17)	Disagree (18)	Strongly disagree (19)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in North America (1)	○	○	○	○	○	○	○
Struggling to find competent **delivery methods** are a major barrier for CRISPR gene editing implementation in North America (2)	○	○	○	○	○	○	○
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in North America (3)	○	○	○	○	○	○	○
Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in North America (4)	○	○	○	○	○	○	○
Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in North America (5)	○	○	○	○	○	○	○
Off-target effects are a major barrier for CRISPR gene editing implementation in North America (6)	○	○	○	○	○	○	○
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a	○	○	○	○	○	○	○

major barrier for CRISPR gene editing implementation in North America (7)							
High development and implementation costs are a major barrier for CRISPR gene editing implementation in North America (10)	o	o	o	o	o	o	o
The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in North America (11)	o	o	o	o	o	o	o

Display This Question:
If Q4 = South America

Q47 Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in **South America:**

	Strongly agree (13)	Agree (14)	Somewhat agree (15)	Neither agree nor disagree (16)	Somewhat disagree (17)	Disagree (18)	Strongly disagree (19)
Policy/Legal issues are a major barrier for CRISPR gene editing implementation in South America (1)	o	o	o	o	o	o	o
Struggling to find competent **delivery methods** are a major barrier for CRISPR gene editing implementation in South America (2)	o	o	o	o	o	o	o
Lack of fundamental knowledge about **gRNA design** is a major barrier for CRISPR gene editing implementation in South America (3)	o	o	o	o	o	o	o

Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in South America (4)	○	○	○	○	○	○	○
Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in South America (5)	○	○	○	○	○	○	○
Off-target effects are a major barrier for CRISPR gene editing implementation in South America (6)	○	○	○	○	○	○	○
The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in South America (7)	○	○	○	○	○	○	○
High development and implementation costs are a major barrier for CRISPR gene editing implementation in South America (10)	○	○	○	○	○	○	○
The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in South America (13)	○	○	○	○	○	○	○

Page Break

Display This Question:
If Q4 = Africa

Q15 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **Africa**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	o	o	o	o	o	o	o	o
Maize (2)	o	o	o	o	o	o	o	o
Soybean (3)	o	o	o	o	o	o	o	o
Rice (4)	o	o	o	o	o	o	o	o
Potatoes (5)	o	o	o	o	o	o	o	o
Cassava (8)	o	o	o	o	o	o	o	o
Sorghum (9)	o	o	o	o	o	o	o	o
Millet (10)	o	o	o	o	o	o	o	o
Yams (11)	o	o	o	o	o	o	o	o
Plantains (12)	o	o	o	o	o	o	o	o
Vegetables (if yes, please specify) (17)	o	o	o	o	o	o	o	o
Fruits (if yes, please specify) (18)	o	o	o	o	o	o	o	o
Legumes (if yes, please specify) (19)	o	o	o	o	o	o	o	o
Other (if yes, please specify) (16)	o	o	o	o	o	o	o	o

Display This Question:

If Q4 = Asia

Q48 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **Asia**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	○	○	○	○	○	○	○	○
Maize (2)	○	○	○	○	○	○	○	○
Soybean (3)	○	○	○	○	○	○	○	○
Rice (4)	○	○	○	○	○	○	○	○
Potatoes (5)	○	○	○	○	○	○	○	○
Cassava (8)	○	○	○	○	○	○	○	○
Sorghum (9)	○	○	○	○	○	○	○	○
Millet (10)	○	○	○	○	○	○	○	○
Yams (11)	○	○	○	○	○	○	○	○
Plantains (12)	○	○	○	○	○	○	○	○
Vegetables (if yes, please specify) (13)	○	○	○	○	○	○	○	○
Fruits (if yes, please specify) (14)	○	○	○	○	○	○	○	○
Legumes (if yes, please specify) (15)	○	○	○	○	○	○	○	○

Other (if yes, please specify) (6)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = Europe

Q49 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **Europe**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	○	○	○	○	○	○	○	○
Maize (2)	○	○	○	○	○	○	○	○
Soybean (3)	○	○	○	○	○	○	○	○
Rice (4)	○	○	○	○	○	○	○	○
Potatoes (5)	○	○	○	○	○	○	○	○
Cassava (8)	○	○	○	○	○	○	○	○
Sorghum (9)	○	○	○	○	○	○	○	○
Millet (10)	○	○	○	○	○	○	○	○
Yams (11)	○	○	○	○	○	○	○	○
Plantains (12)	○	○	○	○	○	○	○	○
Vegetables (if yes, please specify) (13)	○	○	○	○	○	○	○	○
Fruits (if yes, please specify) (14)	○	○	○	○	○	○	○	○

Legumes (if yes, please specify) (15)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (6)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = Oceania

Q50 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **Oceania**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	○	○	○	○	○	○	○	○
Maize (2)	○	○	○	○	○	○	○	○
Soybean (3)	○	○	○	○	○	○	○	○
Rice (4)	○	○	○	○	○	○	○	○
Potatoes (5)	○	○	○	○	○	○	○	○
Cassava (8)	○	○	○	○	○	○	○	○
Sorghum (9)	○	○	○	○	○	○	○	○
Millet (10)	○	○	○	○	○	○	○	○
Yams (11)	○	○	○	○	○	○	○	○
Plantains (12)	○	○	○	○	○	○	○	○
Vegetables (if yes, please specify) (13)	○	○	○	○	○	○	○	○

Fruits (if yes, please specify) (14)	○	○	○	○	○	○	○	○
Legumes (if yes, please specify) (15)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (6)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = North America

Q51 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **North America**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	○	○	○	○	○	○	○	○
Maize (2)	○	○	○	○	○	○	○	○
Soybean (3)	○	○	○	○	○	○	○	○
Rice (4)	○	○	○	○	○	○	○	○
Potatoes (5)	○	○	○	○	○	○	○	○
Cassava (8)	○	○	○	○	○	○	○	○
Sorghum (9)	○	○	○	○	○	○	○	○
Millet (10)	○	○	○	○	○	○	○	○
Yams (11)	○	○	○	○	○	○	○	○
Plantains (12)	○	○	○	○	○	○	○	○
Vegetables (if yes,	○	○	○	○	○	○	○	○

please specify) (13)								
Fruits (if yes, please specify) (14)	○	○	○	○	○	○	○	○
Legumes (if yes, please specify) (15)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (6)	○	○	○	○	○	○	○	○

Display This Question:
If Q4 = South America

Q52 What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in **South America**? Rate each on a scale from 1 to 7.

	Extremely likely (71)	Moderately likely (72)	Slightly likely (73)	Neither likely nor unlikely (74)	Slightly unlikely (75)	Moderately unlikely (76)	Extremely unlikely (77)	I don´t know (78)
Wheat (1)	○	○	○	○	○	○	○	○
Maize (2)	○	○	○	○	○	○	○	○
Soybean (3)	○	○	○	○	○	○	○	○
Rice (4)	○	○	○	○	○	○	○	○
Potatoes (5)	○	○	○	○	○	○	○	○
Cassava (8)	○	○	○	○	○	○	○	○
Sorghum (9)	○	○	○	○	○	○	○	○
Millet (10)	○	○	○	○	○	○	○	○
Yams (11)	○	○	○	○	○	○	○	○
Plantains (12)	○	○	○	○	○	○	○	○

Vegetables (if yes, please specify) (13)	○	○	○	○	○	○	○	○
Fruits (if yes, please specify) (14)	○	○	○	○	○	○	○	○
Legumes (if yes, please specify) (15)	○	○	○	○	○	○	○	○
Other (if yes, please specify) (6)	○	○	○	○	○	○	○	○

Page Break

Display This Question:
If Q4 = Africa

Q17 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **Africa**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)	○	○	○	○	○	○	○
Reduced environmental damage in agricultural production (2)	○	○	○	○	○	○	○
Increased nutritional value in crops (3)	○	○	○	○	○	○	○
Increased producer profits (4)	○	○	○	○	○	○	○
Increased yields (5)	○	○	○	○	○	○	○
Reduced yield variability (6)	○	○	○	○	○	○	○
Other (if yes, please specify) (8)	○	○	○	○	○	○	○

Display This Question:

If Q4 = Asia

Q53 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **Asia**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)	o	o	o	o	o	o	o
Reduced environmental damage in agricultural production (2)	o	o	o	o	o	o	o
Increased nutritional value in crops (3)	o	o	o	o	o	o	o
Increased producer profits (4)	o	o	o	o	o	o	o
Increased yields (5)	o	o	o	o	o	o	o
Reduced yield variability (6)	o	o	o	o	o	o	o
Other (if yes, please specify) (8)	o	o	o	o	o	o	o

Display This Question:
If Q4 = Europe

Q52 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **Europe**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)	o	o	o	o	o	o	o
Reduced environmental damage in agricultural production (2)	o	o	o	o	o	o	o

Increased nutritional value in crops (3)	◯	◯	◯	◯	◯	◯	◯
Increased producer profits (4)	◯	◯	◯	◯	◯	◯	◯
Increased yields (5)	◯	◯	◯	◯	◯	◯	◯
Reduced yield variability (6)	◯	◯	◯	◯	◯	◯	◯
Other (if yes, please specify) (8)	◯	◯	◯	◯	◯	◯	◯

Display This Question:
If Q4 = Oceania

Q51 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **Oceania**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)	◯	◯	◯	◯	◯	◯	◯
Reduced environmental damage in agricultural production (2)	◯	◯	◯	◯	◯	◯	◯
Increased nutritional value in crops (3)	◯	◯	◯	◯	◯	◯	◯
Increased producer profits (4)	◯	◯	◯	◯	◯	◯	◯
Increased yields (5)	◯	◯	◯	◯	◯	◯	◯
Reduced yield variability (6)	◯	◯	◯	◯	◯	◯	◯
Other (if yes, please specify) (8)	◯	◯	◯	◯	◯	◯	◯

Display This Question:
If Q4 = North America

Q50 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **North America**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)							
Reduced environmental damage in agricultural production (2)							
Increased nutritional value in crops (3)							
Increased producer profits (4)							
Increased yields (5)							
Reduced yield variability (6)							
Other (if yes, please specify) (8)							

Display This Question:
If Q4 = South America

Q49 What are (or will be) the major beneficiaries of CRISPR gene editing adoption in **South America**? Rate each option on a scale from 1 to 7.

	1 (No beneficiary) (1)	2 (4)	3 (5)	4 (Medium beneficiary) (2)	5 (6)	6 (7)	7 (Major beneficiary) (3)
Reduced food insecurity (1)							
Reduced environmental damage in agricultural production (2)							
Increased nutritional value in crops (3)							

Increased producer profits (4)	○	○	○	○	○	○	○
Increased yields (5)	○	○	○	○	○	○	○
Reduced yield variability (6)	○	○	○	○	○	○	○
Other (if yes, please specify) (8)	○	○	○	○	○	○	○

Page Break

End of Block: Applications & Barriers

Start of Block: Statements & Final remarks

Q53 To what extent do you agree with the following statements on CRISPR gene editing:

	Strongly agree (1)	Agree (2)	Somewhat agree (3)	Neither agree nor disagree (4)	Somewhat disagree (5)	Disagree (6)	Strongly disagree (7)
CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation. (1)	○	○	○	○	○	○	○
CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues (3)	○	○	○	○	○	○	○
CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries (4)	○	○	○	○	○	○	○
Off-targeted editing is a significant threat for CRISPR gene editing in	○	○	○	○	○	○	○

plant breeding (5)							
Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market (8)	○	○	○	○	○	○	○
CRISPR gene editing patents will primarily be owned by large plant breeding multinationals (7)	○	○	○	○	○	○	○
In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology (9)	○	○	○	○	○	○	○
The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector (10)	○	○	○	○	○	○	○
The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role (11)	○	○	○	○	○	○	○
CRISPR gene editing will remain an	○	○	○	○	○	○	○

expensive technology and therefore primarily be applied in developed countries (12)

Page Break

Q21 If you have any final remarks concerning the answers you gave in the survey or the questions that were asked, please leave them here.
Also, in case you are interested in the results of this study please leave your e-mail address here for future correspondence.

End of Block: Statements & Final remarks

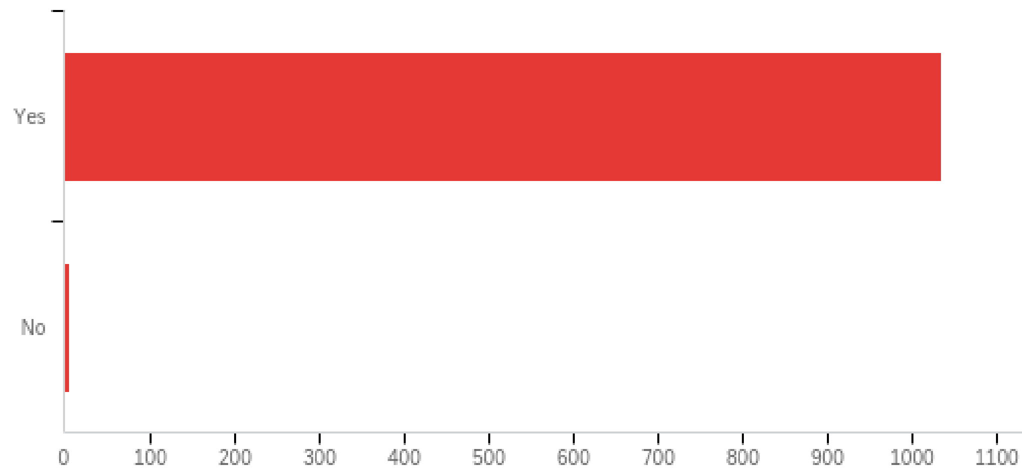
Appendix B: Export survey results

Default Report

CRISPR Drivers, Barriers & Prospects – A comparative study among plant scientists globally.

November 9th 2021, 5:27 am MST

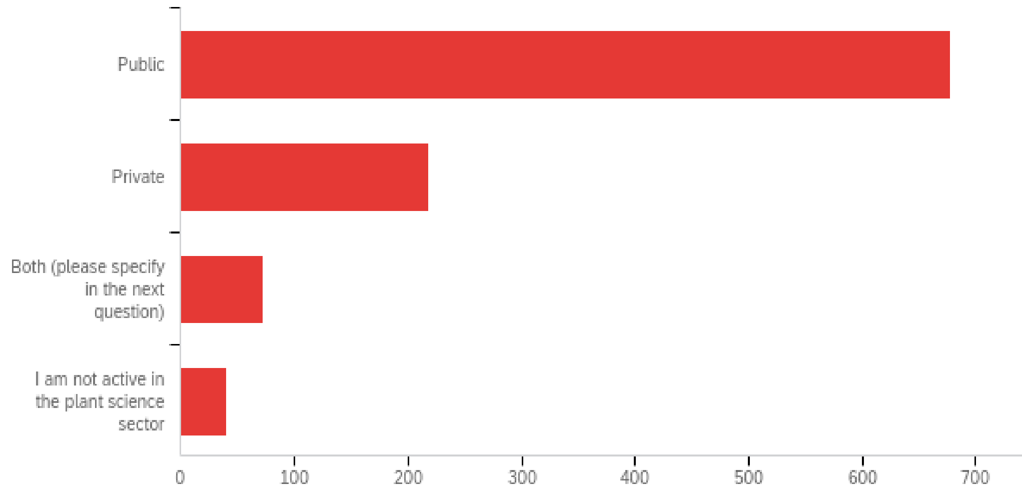
Q31 – I am over the age of 18 and I would like to participate in this research



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	I am over the age of 18 and I would like to participate in this research	1.00	2.00	1.00	0.07	0.00	1040

#	Answer	%	Count
1	Yes	99.52%	1035
2	No	0.48%	5
	Total	100%	1040

Q27 – Are you active in the public or private plant science sector?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Are you active in the public or private plant science sector?	1.00	4.00	1.48	0.79	0.63	1009

#	Answer	%	Count
1	Public	67.20%	678
2	Private	21.70%	219
3	Both (please specify in the next question)	7.14%	72
4	I am not active in the plant science sector	3.96%	40
	Total	100%	1009

Q1 – Please indicate how much of your time (in %) you are active in the public and/or private plant science sector:

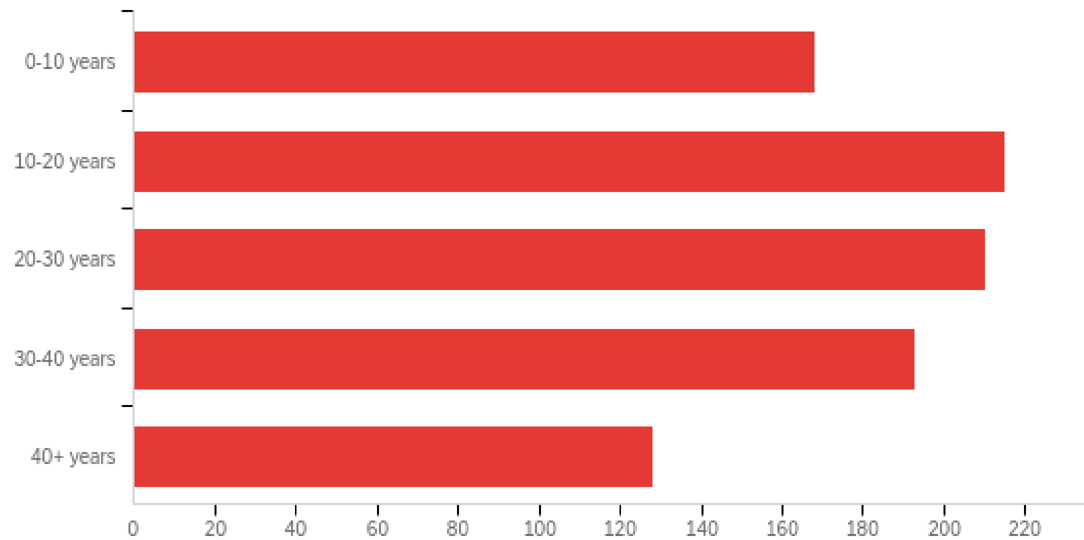
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Distribution public/private sector	5.00	100.00	58.59	26.79	717.92	68

#	Answer	%	Count
5	5	1.47%	1
9	9	1.47%	1
10	10	2.94%	2
12	12	1.47%	1
18	18	1.47%	1
20	20	5.88%	4
25	25	2.94%	2
28	28	1.47%	1
30	30	4.41%	3
40	40	1.47%	1
50	50	20.59%	14
60	60	5.88%	4
61	61	2.94%	2
67	67	1.47%	1
70	70	7.35%	5
71	71	2.94%	2
72	72	1.47%	1
75	75	1.47%	1
80	80	7.35%	5
81	81	2.94%	2
82	82	1.47%	1
83	83	1.47%	1

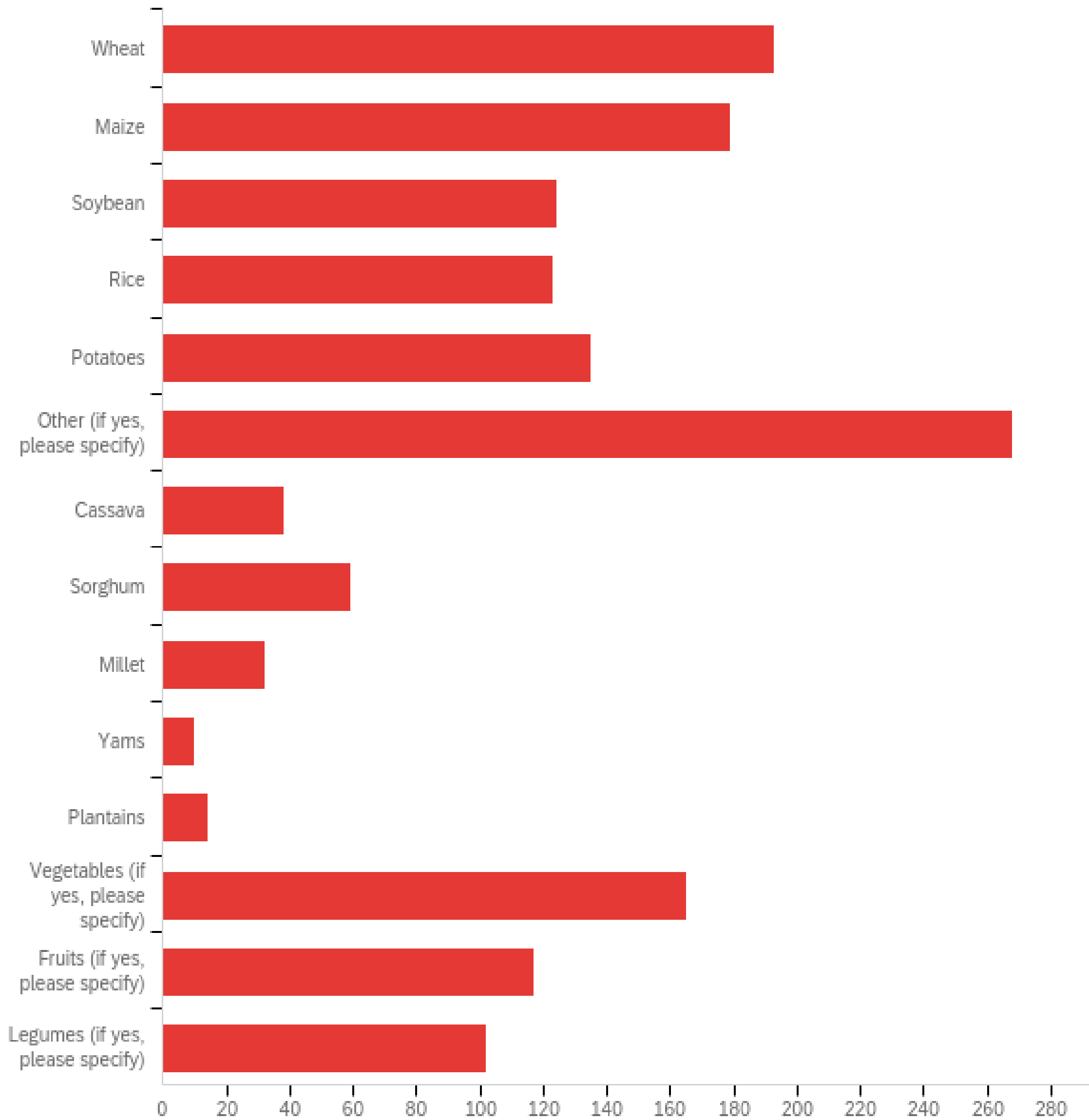
87	87	1.47%	1
90	90	7.35%	5
100	100	8.82%	6
	Total	100%	68

Q2 – How many years of experience do you have in the plant science sector?

Unable to export widget. Please contact Qualtrics Support.



Q25 – Which crops are you primarily working in?



#	Answer	%	Count
1	Wheat	12.38%	193
2	Maize	11.48%	179
3	Soybean	7.95%	124
4	Rice	7.89%	123
5	Potatoes	8.66%	135
6	Other (if yes, please specify)	17.19%	268

7	Cassava	2.44%	38
8	Sorghum	3.78%	59
9	Millet	2.05%	32
10	Yams	0.64%	10
11	Plantains	0.90%	14
15	Vegetables (if yes, please specify)	10.58%	165
16	Fruits (if yes, please specify)	7.50%	117
17	Legumes (if yes, please specify)	6.54%	102
	Total	100%	1559

Q25_6_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
vanilla, aloe
Taxus
canola
Cotton
Arabidopsis
tobacco
Arabidopsis
citrus
insects
Sweetpotato
oil crops
oat
Barley
Barley, oat
oilseeds
not crop: bryophyte

Brassica napus
rapeseed, sugarbeet
Diverse, including models Arabidopsis, Physcomitrium
All crops listed on Annex 1 of the Ithernational Seed Treaty (http://www.fao.org/fileadmin/templates/agphome/documents/PGR/PubPGR/ResourceBook/annex1.pdf)
tobacco
sweet potato, coconut
Brassicaceae
Wild herbs, arabidopsis
Cucumber, garlic, Sesame
cannabis, melon
Rapeseed
Arabidopsis
Brachypodium, Fagopyrum
Barley
Forest trees
barley, hop
barley, N. benthamiana
poplar
actinorhizal plants and silkworm host plants
Poplar, Eucaliptus, Sunflower
Barley, Amaranth, Sunflower
Arabidopsis thaliana
Rapeseed
cotton
Tobacco
arabidopsis
tomato
greengram, cotton, peanut

Small orphan grains eg tef, fonio
Barley
Algae
cotton, Arabidopsis
barley
Barley
triticale
No crops, Arabidopsis
Cotton
Ornamentals
Camelina
Arabidopsis
Model species (Ath, Nbenth)
model species and wild flowers
cotton
oak species
grapes, nicotiana benthamiana
trees
ornamental and medicinal plants and oilseed rape
Microalgae
quinoa, barley
barley
Cotton, canola
bamboo， Chinese fir
Eucalyptus
canola
Tobacco
duckweeds, orchids, woody plants, medicinal orchids

barley
as suits
Cactus; Cycas
Nicotiana benthamiana
Sunflower
beet (sugar and table) and dry bean
forest trees
Arabidopsis
actinorhizal plants (Datisca glomerata, Casuarina glauca, Coriaria spp.)
ornamentals
Poplar (populus)
cotton
Ornamental cross
Arabidopsis and tomato
ornamentals
sorghum, sunflower
barley
Energy, industrial and fibre crops
Alstroemeria
Groundnut, pigeonpea, small millets
Arabidopsis
Ornamentals
Chmel – Hop
Not working on crop plants
barley, tomato
Arabidopsis
ornamentals
barley, sulla, vetch

hedge plants
Cross-crop technology
flowers
Orphan Crops
Cotton, oilseed rape
Gerbera
poplar
chrysanthemum
barley
Flowers
Arabidopsis
Arabidopsis thaliana
coffee
Arabidopsis
ornamentals
Genetic Models: Arabidopsis and Brachypodium
medicinal plants
Popcorn
Barley, brassicaceae
ornamentals
olive, coffee
Ornamental flowers
I don’t work on crops
Trees
Arabidopsis (no crops)
Arabidopsis
Medicinal plants
Flower seeds

Pine
Sunflower
agroforestry spp,
Populus
Bananas
No crops. Arabidopsis and poplar.
Sunflower
ornamentals
Radish hemp
Coffee
trees: aspen, Norway spruce
Conifers
trees
Not working on crops, only model plants
tea, coffee, cocoa
Medicinal plants
Sunflowers
Grassland
Not crop plants
Camelina, cereal rye
rangeland and forest
forage and feed
marine algae
Turf grasses
Industrial Crops
Barley
Cannabis and essential oils
oilseed rape, cotton

Barley
PAULOWNIA
COTTON SEED
Quinoa, Flax, Greengram, Bambara nut
Sunflower & Model plants
WOSR, Sunflower, Peas, FabaBeans, Forrage & Grasses
Rye
flowering pot plants
forage grasses
Forest trees
Arabidopsis
cotton
switchgrass, 92ultination, poplar
model Arabidopsis
Mango
Seeds Canada represents over 50 different crop kinds
bioenergy trees (poplar)
Arabidopsis
perennial ryegrass
ornamental crops & Trees
Duckweed
alternat6ive rubber and latex crops
Drumsticks(Saijan), breadfruit
Alfalfa and Hay
mint, yacon
potplants
BY-2 tobacco
Chrysanthemum

barley, oat, /rye
hop
Cotton, oilseed rape
canola, Arabidopsis
OSR
Petunia
Barley
Sunflower
Forest trees
pot and bedding
oilseed rape, cotton
Barley
Trees, Poplar and Spruce
oilseed rape
barley, it's focused on starch
Oat: Hop
flowers
peanut
trees
tobacco
ornamentals: Carnation, chrysanthemum; alstroemeria
ornamentals
specialty crops
horticulture
Barley
barley
Brassica napus, but mostly no crops using the model plant A. thaliana
not a crop

Barely, Triticale
coffee, cashew, cork oak
Forage grasses
Sunflower
Sunflower
Date Palm
switchgrass and forest trees
sugar beet
sugar beet
Oil seed rape
grapevine, olive
Barley, oats rye
No applicable- I do not work directly on crops
basil
ornamental plants
forage crops
Ornamentals
non-edible plants
Tomato
Fodder crops
Barley, Arabidopsis
ornamentals
Barley
chicory
hemp, barley
Tobacco
cannabis
Echinacea, Limonium and Helleborus

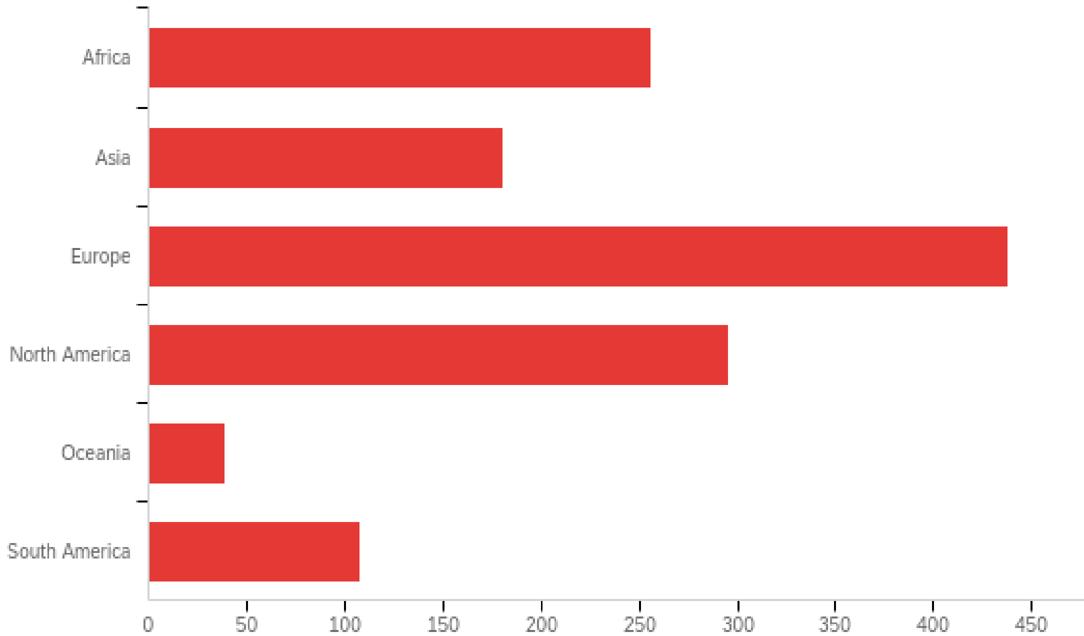
Dianthus
sugar beet
potplants
Arabidopsis
Poplar
Trees
rose
Sugar beet
Bioenergy, turf
Tea
Ornamentals
groundnuts
Olea europaea, Avena spp.
Sugar beet and chicory
Arabidopsis
cacao
oaks
barley
poplar trees
Forage species
Ornamental Bromeliads
Landscape Plants
Rye, Barley, Oats
trees
trees
Arabidopsis
Linseed, Oilseed Rape, Canary Seed, Borage, Oats
Arabidopsis

oil and fiber crops
Eucalyptus
Sugarcane
African trees
models: Arabidopsis, Marchantia
barley
barley
Arabidopsis
Fodder grasses
ornamentals
Ornamentals
Nutritious orphan crops, including fruits, vegetables, grains, roots
Forage crops, Cover crop
Trees, mostly from the Populus genus (poplars, aspens, willows and hybrids)
Pine Trees
Arabidopsis thaliana
Using Arabidopsis as model
none, I am not doing field or lab work
poplar, spruce, pine
Ornamental crops
Arabidopsis, Chlamydomonas, cyanobacteria, Norway spruce
Pine
grasslands, forests, arable
Tree species
fundamental science only
rye, oat, Russian dandelion
Arabidopsis
Barley

Sunflower
Forest trees
Model plant Arabidopsis and poplar trees
Poplar and Arabidopsis
Sugarcane
Barley
herbs
no crops, just Arabidopsis thaliana
indoor crops (veggies + ornamentals), outdoor ornamentals (flowerbulbs, flowers)
poplar, chicoree; - no specific focus
Arabidopsis, carnivorous plants
Strawberries
Poplar
Trees
barley
sweetpotato, forage crops
orchids
Other model species but no crops
No crop, Arabidopsis
Barley
Chrysanthemum
cotton
Bananas
oilseeds
Miscanthus, sugarcane, energycane
Cotton
weeds
algae

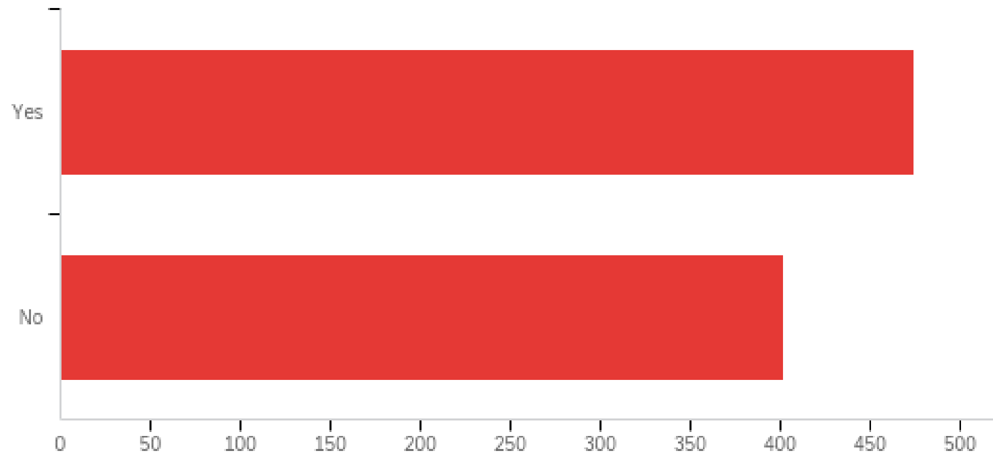
Canola/Rapeseed
Cotton
ornamentals: Rhododendron canescens, gerbera, flowering dogwood
Camelina sativa, Ethiopian mustard
ornamentals
Ornamental plants
camelina
Weeds
Turfgrass
Ornamental woody landscape plants
arabidopsis
Arabidopsis
hemp
switchgrass
Ornamental plants
Barley
ginger, boxwoods
hops
cotton
Weeds

Q4 – Which regions are of primary focus concerning the R&D activities of your research group/department? Note: please indicate in which countries the department you work in is actively conducting R&D



#	Answer	%	Count
1	Africa	19.45%	256
2	Asia	13.68%	180
3	Europe	33.28%	438
4	North America	22.42%	295
5	Oceania	2.96%	39
6	South America	8.21%	108
	Total	100%	1316

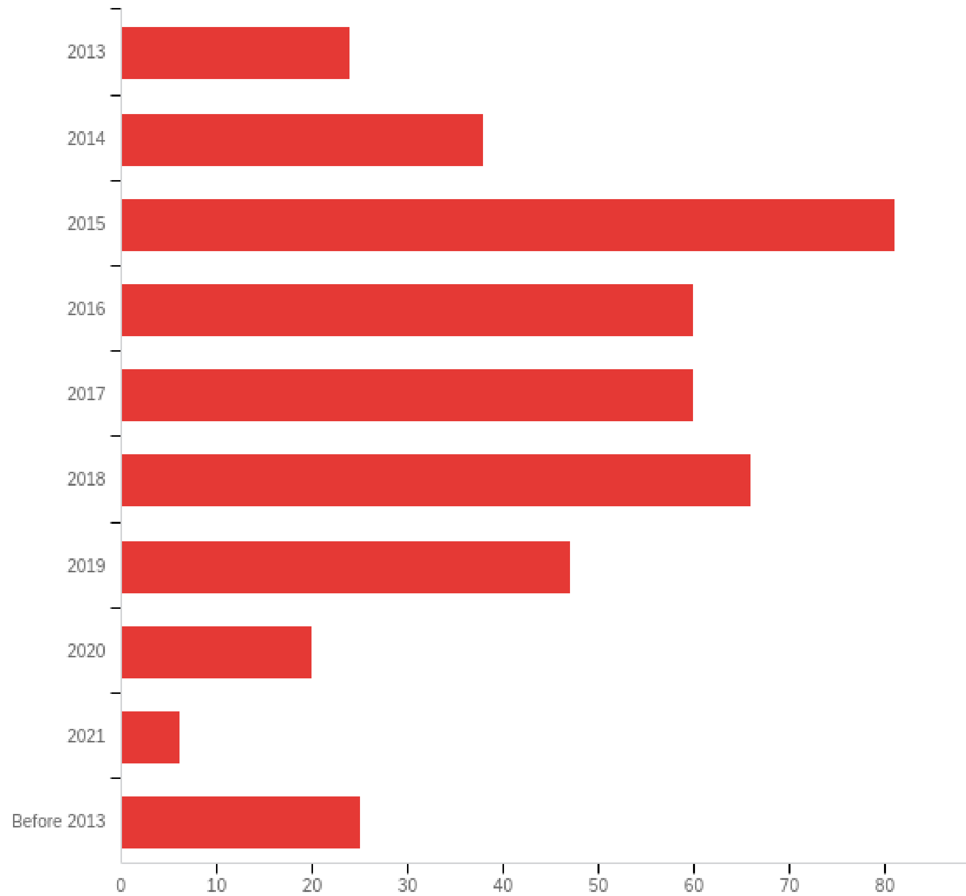
Q13 – Is your research group/department active in CRISPR gene editing Research & Development?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is your research group/department active in CRISPR gene editing Research & Development?	1.00	2.00	1.46	0.50	0.25	876

#	Answer	%	Count
1	Yes	54.11%	474
2	No	45.89%	402
	Total	100%	876

Q5 – When did your research group/department start their CRISPR gene editing Research & Development? Note: Starting in this context means, R&D budget was allocated for the first time to explore the potential of the CRISPR gene editing technology.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	When did your research group/department start their CRISPR gene editing Research & Development? Note: Starting in this context means, R&D budget was allocated for the first time to explore the potential of the CRISPR gene editing technology.	4.00	13.00	7.85	2.30	5.28	427

#	Answer	%	Count
4	2013	5.62%	24
5	2014	8.90%	38
6	2015	18.97%	81
7	2016	14.05%	60
8	2017	14.05%	60

9	2018	15.46%	66
10	2019	11.01%	47
11	2020	4.68%	20
12	2021	1.41%	6
13	Before 2013	5.85%	25
	Total	100%	427

Q6 – Could you indicate for your research group/department, what percentage of the total R&D budget is currently allocated to CRISPR gene editing Research & Development?

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Africa	2.00	100.00	21.90	20.58	423.68	87
2	Asia	1.00	100.00	27.31	24.13	582.33	90
3	Europe	1.00	100.00	21.52	20.76	430.87	180
4	Oceania	1.00	85.00	28.38	28.65	820.86	16
5	North America	1.00	100.00	25.50	24.29	589.92	120
6	South America	1.00	70.00	17.39	16.35	267.42	44

Q7 – Could you indicate for your research group/department, what percentage of the total R&D budget do you envision will be allocated to CRISPR gene editing Research & Development in 3, 5 and 10 years?

Africa

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	100.00	22.47	20.55	422.45	141
2	in 5 years	0.00	100.00	28.05	21.73	472.12	147
3	in 10 years	0.00	100.00	34.68	25.99	675.59	149

Asia

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	100.00	26.64	22.07	486.91	109
2	in 5 years	0.00	100.00	31.76	23.71	562.39	104
3	in 10 years	0.00	100.00	33.63	24.36	593.65	93

Europe

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	100.00	22.42	21.28	452.91	249
2	in 5 years	0.00	100.00	26.09	21.80	475.46	245
3	in 10 years	0.00	100.00	30.24	22.57	509.36	233

North America

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	100.00	23.27	23.56	555.15	187
2	in 5 years	0.00	100.00	26.66	21.72	471.94	183
3	in 10 years	0.00	100.00	30.90	22.20	493.01	175

Oceania

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	90.00	25.86	27.54	758.66	22
2	in 5 years	0.00	90.00	32.43	28.63	819.86	21

3	in 10 years	5.00	85.00	32.82	22.06	486.50	17

South America

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	in 3 years	0.00	80.00	20.21	17.95	322.22	67
2	in 5 years	0.00	80.00	26.71	18.25	333.04	65
3	in 10 years	0.00	90.00	33.63	22.10	488.39	62

Q23 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in Africa? Rate each on a scale from 1 to 7. Note: 104ultinatio development and implementation in this context means that the corresponding function can 104ultinationa be developed for, and applied to multiple crops grown in the region.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	85.00	92.00	88.23	2.45	6.01	180
2	Drought resistance	85.00	92.00	88.72	2.12	4.47	189
3	Salt soil resistance	85.00	92.00	88.23	2.41	5.82	180
4	Insect resistance	85.00	92.00	89.14	2.02	4.09	182
5	Biofortification	85.00	92.00	89.14	2.14	4.60	181
6	Fungus resistance	85.00	92.00	88.98	1.94	3.75	186
7	Viruses resistance	85.00	92.00	89.33	1.88	3.54	184
8	Increased shelf life	85.00	92.00	88.47	2.35	5.51	178
9	Fertilizer use efficiency	85.00	92.00	88.57	2.39	5.72	183
10	Improved cultivation	85.00	92.00	88.82	2.38	5.68	179
11	Other (if yes, please specify)	85.00	92.00	89.33	2.81	7.90	69

Unable to export widget. Please contact Qualtrics Support.
Unable to export widget. Please contact Qualtrics Support.
Unable to export widget. Please contact Qualtrics Support.
Q23_8_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
bacterial resistance
Bacteria resistance
Bacterial resistance

breeding tools
not applicable
varieties adapted to high Acid soil
Improved medicinal compound production
unknown
Processing/industrial aplications
improved seed production quality
secret
Breeding
nutrition/quality
Resistance to bacterial disease
none
Improved expression hosts
Yield
palatability, digestibility, loss of toxins
No
acid soil tolerance
Special Starch
nematode resistance
Striga resistance
Nutrient acquisition ability, novel bio products
Integration into mixed production systems (architecture, phenology)
Increased yield
Yes
No
Striga resistance
No
No

nitrogen fixation

grain aroma & quality

Q14 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in Africa:

Unable to export widget. Please contact Qualtrics Support.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Africa	13.00	54.00	17.91	10.94	119.65	177
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Africa	13.00	54.00	18.72	11.22	125.78	175
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Africa	13.00	55.00	19.32	11.68	136.34	177
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Africa	13.00	54.00	18.86	11.04	121.84	175
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Africa	13.00	52.00	18.23	10.89	118.69	175
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Africa	13.00	55.00	20.12	11.54	133.24	174
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Africa	13.00	55.00	20.01	11.43	130.61	175
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in Africa	13.00	54.00	18.10	11.40	129.90	173
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Africa	13.00	55.00	18.16	11.60	134.66	177

Q15 – What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in Africa? Rate each on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	73.38	2.46	6.04	156
2	Maize	71.00	78.00	72.03	1.86	3.47	163
3	Soybean	71.00	78.00	72.87	2.30	5.27	156
4	Rice	71.00	78.00	73.20	2.45	5.98	158
5	Potatoes	71.00	78.00	73.40	2.24	5.03	160
6	Cassava	71.00	78.00	73.02	2.35	5.53	161
7	Sorghum	71.00	78.00	73.38	2.36	5.58	159
8	Millet	71.00	78.00	74.01	2.46	6.08	158
9	Yams	71.00	78.00	74.54	2.56	6.58	158
10	Plantains	71.00	78.00	74.09	2.74	7.52	158
11	Vegetables (if yes, please specify)	71.00	78.00	74.35	2.91	8.48	78
12	Fruits (if yes, please specify)	71.00	78.00	74.51	2.80	7.83	71
13	Legumes (if yes, please specify)	71.00	78.00	73.56	2.58	6.67	80
14	Other (if yes, please specify)	71.00	78.00	75.48	2.95	8.69	54

Unable to export widget. Please contact Qualtrics Support.

Q17 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in Africa? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.63	1.62	2.62	172
2	Reduced environmental damage in agricultural production	1.00	7.00	3.59	1.79	3.22	170
3	Increased nutritional value in crops	1.00	7.00	3.83	1.80	3.24	169
4	Increased producer profits	1.00	7.00	3.87	1.93	3.73	167
5	Increased yields	1.00	7.00	4.16	1.87	3.49	171
6	Reduced yield variability	1.00	7.00	3.83	1.81	3.27	166
7	Other (if yes, please specify)	1.00	7.00	2.19	1.52	2.32	37

Unable to export widget. Please contact Qualtrics Support.

Q21 – If you have any final remarks concerning the answers you gave in the survey or the questions that were asked, please leave them here. Also, in case you are interested in the results of this study please leave your e-mail address here for future correspondence.

If you have any final remarks concerning the answers you gave in the survey or the questions that were asked, please leave them here. Also, in case you are interested in the results of this study please leave your e-mail address here for future correspondence.
Funding needs to be increased
The main expense for using gene editing relates to current patents on the technology. This could impede the use of gene editing in the future, and may also reduce the breadth of traits that are improved as the technology will be limited to large corporations that are interested in profit. Also, the asynchrony in global regulation of the technology is very problematic regardless of the country you reside in due to trade.
Concerning the last questions on private companies holding patents, I disagree with the hope that the public sector will not left behind due to unreasonable regulatory constrains as in the case of the GMO product.
CRISPR-edited plants should be considered GMO as they integrate foreign DNA. If you just integrate Indels not. This does not become clear from your question.
Some of the questions couldn't be answered without further specification/differentiation, for example, if CRISPR/Cas should be regulated as GMO ->this depends on the application (SDN 1, 2 or 3). Also, the questions about IP will be dependent on how the technology will be regulated (in case all form of GE will be considered as GMO, it will be more difficult for SME to get access to the technology).
In deed! The regulations and funding structure are big lacunae in countries like India.
A major barrier which was not covered will be the lack of trained and knowledgeable scientists in Africa. Poorly developed seed systems will remain a barrier – although this is not specific to gene editing. You did not include any factors on gender! This is an omission. Who will benefit in Africa. Will is be smallholder women farmers, or large scale industrial production eg. Men?
GE now is a great idea to complement breeding; improve the existing cultivars; identify the mutations in hundreds of cultivars and edit to improve all traits; even the developing countries can be trained; if CRISPR people give the constructs free to all.
Thanks! Interesting and hopefully useful.
I hope you willrobtain feedback from the public as well.

Yes, I would like to receive the study results. Please do share with me on the following email address;

CRISPR is a revolution in agriculture, its hard to know where we will be in 10 years but I would not be surprised if a new technology supersedes it. Also the power of CRISPR is limited by ability to do HDR- currently very difficult in plants.

I´m interested in the results of this study.

I have assumed that EU will continue to maintain its position of GE being a form of GM, and that GM is politically unacceptable as a cultivation process within EU. Sadly I see no imminent change in the EC's thinking on how to regulate GE and the recently published report (April 2021) on New genomic techniques under Union law was a classic example of kicking the can down the road (i.e. putting of making a decision). I have zero expectation that EU will adopt GM/GE crops in the next decade or beyond, whereas as N. America and others countries (including the ex-EU UK) will move forward to embrace these new technologies.

CRIPR CAS is very important technology and it is need of the hour

Questions not well designed for academic researchers like me. Often no choice applies.

UK and mainland Europe are in the early stages of undergoing regulatory divergence on GM/Edited plants so difficult to answer for Euarope as a whole.

Nil

To me, the issue with CRISPR or GMOs in general is not the technology itself, but how we use it. Using technology to be able to sell sliced apples in plastic boxes does not make sense and actually should be forbidden in a context of energy shortage and climate change. Using these technologies to introduce new resistance genes to diseases in nutritionally good and tasty cultivars, is very relevant, but does not happen... So, questions should not focus on the technology, but on the purpose. It is not because we can do something, that we should necessarily do it (and this is true for any technology). Unfortunately this ethical questioning never happens.

The major limitations to applications of gene editing technologies are lack of 109ultinatio regulatory policies, disinformation and lack of knowledge of any form of plant breeding, let alone gene editing. This leads to the issue of a social licence to use technologies which will really benefit producers and consumers. The EU has a lot to blame here in holding back what are exciting new technologies which will help ensure future food availability and benefit the environment. In contrast, most countries in north and south America have approved SDN-1 gene editing, as has S Africa, Australia and Japan, with the UK likely to follow suit.

Good

No further comment. Please email me the results of this study at

Should be keep in loop to avoid the Potential threat of genetic bottleneck

What I think are the risk were never given as an option. Off target effects and gene drives are not the fundamental issues.

I think missing from your questions was about whether we can really go from CRISPR edit (or any other modification) to robust phenotype in the field. To me, that is the bottleneck. Lab/greenhouse results translate poorly.

Current regulatory hurdles not based on science limit CRISPR application A particular problematic regulation is the one limiting editing to ONE gene. In a polyploid species like wheat where you need to edit 3 genomes to have an effect, this regulation is a killer.

It would be great if smaller breeding companies would also have a low cost access to gene-editing techniques in the coming years. It would be such a shame it these techniques would end up being used by large companies only. The public sector should enable the access of these methods to the smaller companies at an affordable cost. My email

No remarks

You should distinguish between CRISPR mediated mutagenesis and CRIPR mediated gene introduction in crop plants

Crispr gene editing questions in a view that no additional bp's are integrated. Only mutation like events that one can find in nature and present food and ornamental crops. One should drive values for the end of the value chain (consumers, society, the greater good). An event can only be successful when a non gmo status is secured for a closed market. Liabilities are a huge risk, licences are very expensive and stewardship systems are a huge cost, which holds back SME companies to apply.

Please share the findings through my email

Please send me a copy of the paper. Thanks.

. Good information-Please publish and publicize. It would be good to dissect responses by continent.

CRISPR gene editing is one extra tool in the plant breeder's toolbox. Not every problem in plant breeding is solved by the use of this tool. In many cases other tools fit better. From a legal perspective it is important to distinguish between the use of CRISPR for the induction of mutations and the use of CRISPR for transgenesis, i.e. creation of new genes or addition of genes from another plant (this can be the same or a different plant species). On the short term (next 5 years) CRISPR will be a research tool helping plant breeders to understand the role of different genes in the expression of a trait. They can apply this knowledge in breeding without creating plant varieties by CRISPR gene editing.

Remarks for Africa, Asia, Europe, and North America are same. Europe has fairly unreasonable CRISPr policies given their involvement in the research. The legal complexities may prevent adoption due to release of events with T-DNA and national responsibility laws.

Gene editing is a simple and inmakes feasible to I products in and for developing countries. The major hurdels are the regulatory framework and the high fees to licence the technology.

No remarks

I don't work with this technology but some of my colleagues do...

I tried my best to give you answers that truly reflect the realities that agriculture will be facing with this new technology in the years to come. However, your survey did not really provide a means to extract a 'thinking-outside-the-box-type' of answers. We need to think pragmatically. GE is another GMO technology that will never be perceived positively by the public when it is applied to producing the food that they eat.. let us not lie about that to ourselves... we should know better as scientists. Any food that is labeled GMO will not be accepted by the public... PERIOD! We just have to accept the fact that GE is a technology like transgenics that will be part of our tool box in the lab for discovery and for advancing knowledge about plant biology. Your survey reminds me of how people think about transgenics back in the 1980s.. very positive and full of naivete without really looking at the bigger picture. Sometimes we scientist need to stop being TOO ARROGANT in forcing to the public a new technology to produce food that the public do not accept. We need to listen. GE as it is applied to crop breeding will never be accepted by the public in the same way that it is accepted when applied to genetic therapy in medicine.

NONE

My lab is doing fundamental research, and we use CRISP/Cas as a tool. We have no I 111ultinat on the development of new CC technologies, hence no budgets are specifically allocated for CC (nor for PCR, nor for..... Otther qietions that I left open is because the correct answer would have been NA for me, but that choiuce did not exist

The questionnaire does not distinguish between benefits per se and benefits that are dependent on the legislation. Costs for CRISPR varieties are for instance high if they are considered as GMOs but low if they are not. The same goes for the likeliness that CRIPPR plants will benefit Europe. Low if considered as GMO, high if not. The questionnaire becomes hard to interpret because the questions do not take these different scenarios into account.

Please note that I am a biotechnologist working on crop plant proteins and polysaccharides in collaborations with plant biologists and biochemists

I'm doing fundamental research on model plants, and very little applied research on crops. Given my background, many of my answers on crops and agriculture are best guesses rather than based on solid insights.

I think that may answers are comparable for the different regions which makes this questionnaire a bit longer than necessary.

Current regulations (in Europe) limit further implementation of CRISPR technologies and therefore Europe will fall behind. Some of the questions in the poll are open for multiple interpretations, its not clear whether the questions are for the current situation or when regulations open up.

ISF had a very nice streaming with interviews of plant breeders and this gave a very nice overview of the problems with CRISPR regulations. The major bottleneck are the different regulations in different countries. The bottleneck is not developing the CRISPR mutation but the regulation.

I anticipate, predictably and sadly, different answers based on geography...

Thanks, please inform me about the outcome of this study at

I have very limited knowledge on CRISPR editing technology and it is highly technical field for researchers in plant breeding and bio-technology. I believe that there are many researchers in Africa who are not aware of the technology

Concerning the last section, I think the market will be dominated by multinationals if things continue as they currently are i.e. the EU remains anti-CRISPR. After the ECJ ruling, many small EU companies were no longer interested in pursuing genome engineering projects. If the EU opens up, then my answers would change. I am interested to learn the results

I found this an unusual survey. It lacked nuance at times – lumping all gene editing technologies together, yet they are hugely different. Targeted 111ultination without foreign DNA in the end product (e.g. removed through breeding) is very different from making new alleles with inserted or altered DNA, or gene drives.

It took more than 5 minutes to answer the questionnaire (more like 10 to 15 minutes).

Be careful interpreting the data as some questions led to a neutral response because the regulatory climate currently does not support the tech, rather than me believing the technology is not relevant for Europe.

The CGIAR centres are currently at the forefront of CRISPR research in Africa. Their role should be emphasized and promoted: they are working with public money from donors, and their findings are always published in Open Access, opening the path to other scientists all over the world. Plus, they do work to enhance the performance of local varieties of interest for the farmers; their germplasm is then transferred to National Research Organizations, which distribute them to farmers at sensible and affordable prices. As long as this technology is mainstreamed through the CGIAR centres, the benefits for smallholders will be clear, transparent and traceable.

You should change your five minutes indication. It takes at least 10.

I'm interested in the results:

the questionare has one major drawback – it refers to Crispr as one technology. Where in fgact when looking at legislation and terminology Crispr actually refers to at least three different variants; 1 – where it is only used to make a cut and let the plant repair (random 112ultination as mentioned by Bobek and the CJEU), 2- where it is made to make small alteraions/mutations – like the one deemed GMO by CJEU (which precisely where ODM tech) and 3 – where it is used to create "classical" transgenic crops. This is not reflected by the questionare, and therefore it is hard to know what has been answered to what. Its more a gray scale than the black and white picture made in the questionare.

Some answers are based on the current legislation, i.e GE plants = GM. If GE plants will still be considered as GM, only big companies will be able to affort the high testing costs. If GE will be deregulated or subjected to a more "soft" testing procedure, the picturen (and my answers) will change. Please send me the result of the study

In my opinion the main challenge is, to identify genes which could be switched-off.

Gene editing is going to be the answer to some of the key challenges of agricultural production and will be major driver for genetic gain acceleration

The questonairy is too long and I disliked to obligation to fill in the 'other'' tick box

Public awareness should be part of research programmes on gene editing tools to defeat misinformation on the technologies. African research institutions should be part of research programs considering a bigger population from the continent Will be consuming gene edited products.

The implementation of CRISPR/cas or any other gene editing technology depends highly on the political decisions which are based on feelings rather than facts. It is still the same old GMO discussion as it was more than 30 years ago. Interestingly, when it come to medical applications, GMOs are most welcome and nobody asks how e.g. vaccines are made.

Greatest challenge is identifying actually useful edits to make on actual target genes – a limitation in biological understanding due to genetic and GxE complexity that showed up nowhere in your questions!

All the concerns about CRISPR (and GMO) are raised from false information. A few questions in this questionnaire looks very childish to me. For example, a few questions mentioning off-target editing. If one has read some research in this area, he/she will know that it is very unlikely for a carefully designed CRISPR to lead to any off-target editing. While rich European counties enjoying their abundant food on dinner tables and spreading first-world "nature is good" mentality, people under the influence of such absurd "mentality" in Africa, Southeast-Asian and LatinaAmerica are dying in empty belly. And those poor people don't even have opportunity to access to knowledge, therefore, no way to defend I from misinformation. Of course, the poor governing system in these regions is another issue, which, as a scientist, I have no idea how to comment. My email is. Please keep me informed of this research.

In several places I only answered for Africa but my answers could be applied to all regions sorry limited time to complete

Way longer than 5 minutes and many questions were limited in their ability to assess all the inputs into agriculture. There is a difference in biotic stress resilience and not becoming infected.

The survey misses a key issue, namely that the technology requires a known gene of major effect to have been identified. It therefore has enormous potential benefits for simply inherited traits but almost none for complex traits; by overlooking this fact, the results of the survey could be quite misleading

Comment: the licensing fees for using CRISPR will keep most small start ups and developing countries from using the technology. Currently, licensing fees are too exorbitant for non-commodity crops to even consider.

Gene editing is targeted towards one or just a few genes. Our biggest challenges for most crops are quantitative traits where there are many (sometimes hundreds) of genes with each one having relatively small effects. I am doubtful that CRISPR will have a major impact on these traits.

Many of the questions did not have a "I don't know" option, so I left them blank. I am a plant scientist, but am not involved in CRISPR or other related technologies in any way, and not familiar with the issues surrounding them.

For some questions that I answered, I looked to the ornamental Bromeliad industry (R&D funds, possibilities with CRISPR). Others I answered for food production in general.

1. The major problem of EU is that public is strongly again GMO in all different kinds of its development. 2. EU researchers can use CRISPR techniques for development and market it all around the world except EU.

If edited plants will be treated/regulated as GMO then the big companies will dominate the market, otherwise they could be an opportunity for public and small companies.

Please keep me posted! Thanks and success with your research!

Interest in the results of the study:

How can the 113ultinational113tion of CRISPR be 113ultinatio with the public desire for truly-agroecological food systems? (If you are going to say: does the public really want agroecological food systems? Is it clear they do.) The issue with CRISPR underpins a larger issue with food systems – which is publics generally poor 'food literacy' and ignorance regarding what is at stake environmentally, nutritionally, personally.

Regulatory barriers imposed by governments risk to limit small companies in exploiting CRISP technologies because only multinational companies can comply with regulations

I'll be happy to learn about the outcome of your survey.

I am interested in the results of this study. Email:

Some questions could not be really answered correctly p.ex the role and 113ultin importance of multinational is not (only) a question of CRISP or not

Was nice going through this survey. I will appreciate having the outcomes and also collaborate with the team if needed as yam is an ophan crop and several aspects of research are yet to be explored Here is email

The primary barrier to commercial gene editing in Europe will continue to be legislation. This will prevent uptake of the benefits across the continent.

I don't think that I'm the right person to answer these questions as I am totally not working in this field and have no knowledge of (or even apinion on) the CRISPR technology.

I would like to see the results of the study, thanks!

This took way more than the 5 minutes that were claimed and I don't know how it could have been done in less. This made me feel negatively about the study and resulted in me (and I assume others) to answer questions less conscienciously than I otherwise might have.

Interesting applications around processability, integration into farming systems (architecture, phenology) and reducing labour costs (e.g., fruit size) for orphan crops

While asking of lot of good questions, this study seems to overlook important aspects regarding agricultural/sylvicultural practices: 1_GM technology, be it achieved through CRISPR or by older, less precise means, is mostly useful to generate a handful of varietals, which does not come close to natural diversity (although it theoretically allows for trait combinations that are not observe in nature, even if they could be viable in nature). These varietal developments require that the same clones be cultivated as per the current dominant model of monocultures. 2_Monocultures spreading I large areas of land, are by far not the most sustainable, or agronomically useful, ways of cultivating crops. They mostly favor short term "efficiency" (lower costs such as reduced workforce, easier harvests with heavy machinery...), at the expense of widespread dissemination of fertilizers and pesticides, soil erosion, open phosphorous cycle, as well as creating favorable conditions for more severe biotic or abiotic stresses (monocultures are not very resilsilient). 3_ The current economic system, which profits in the short term from the wide practice of monocultures, is itself biased with a "free" market model that actually advantages technologically advanced, mechanized farms of the developed countries, at the expense of developing countries' farmers. 4_ If only half of the efforts and funding currently placed behind agricultural biotechnology was put behind mapping the natural variation and diversifying crops (e.g. relying on native crops that are already well adapted to their native environment), a lot of the problems that the CRISPR technology is thought to be able to solve would actually already be solved. 5_ While there are clear legal and political hinders to the development of CRISPR-edited crops, there are at least equally many that prevent a lot of native varietals for many crops from being sold, even if they present good properties (nutritional, biotic or abiotic resistances, ...). Indeed, the "free" market model requires that many locations compete to "select" the optimal producer (most cost efficient in the short term). To allow "fair" competition, only a small subset of the existing varietals for agricultural crops can legally be sold on the market, because grower/farmer/country efficiency (as per market rules) can only be determined if the competitors all grow the same crops. Hence, our current economic model tries to retrofit natural differences into a simpler, less subtle (and arguably dysfunctional) economic model. In this economic model, CRISPR-edited crop are clearly a good fit, but is the model good at all to ensure food security and sustainability? The growing body of evidence and data suggests that it is not, which should lead to question the very relevance of CRISPR-edited crops in the light of which agricultural and economic model they serve.

CRISPR could not only be applied to crops but many other plants and even organisms to improve environmental issues and food security.

Competelion between CRISPR breeding and Genomic assisted breeding would be a key issue

I am looking forward to your results.

Apply a marketing approach to "genome editing" and rename it as "Bio-Evolution" so that people can accept it. The names "Genome Editing" or "CRISPR-CAS9" are totally anti-marketing!

There has to be a better way for science to work with and for society. Scientists could pay more attention to the needs and opinions of the public.

For the results of this study. To me, CRISPR is GMO

Dear Adriaan, An interesting topic. I'm looking forward to the results of the study, please share them at. Concerning patents: Indeed today important patent portfolio's are held by large multinationals. However, given the speed of discovery of new Crispr modes of action, I consider that the importance of those patent portfolio's will decrease. On policies, it will be more and more difficult for Europe to hold its position of labeling Crispr products as GM, when food products/seeds are transported across continents, while at the same time wanting to make its own agriculture greener. I expect that these internal and external forces will make the EU change its policy, only when is hard to estimate.

Thank you for this survey! I just wanted to add that I am primarily active in applied plant breeding (wheat variety development) in a small private company. I do not consider it realistic that my company will implement Crispr directly in the coming 10 years (or even 20-25 years), but I clearly see the huge potential of the technology for plant breeding. I can definitely see our company taking advantage of Crispr products that may be developed at a more fundamental research level. We work in close cooperation with the breeding and pre-breeding activities of the public Swiss federal agriculture research centre, and we also do have several cooperative projects with the academic world (the ETH Zurich in particular). But of course, if ever Crispr implementation should become a reality in Europe, that will depend primarily on a turn in the current political and public opinion perception of the technology. Thank you, I am interested in the survey results: Kind regards

(knowing that results will be anonymous) Interesting survey!

The presence/absence of the CAS transgene in the genome will affect regulation

Thank you for conducting this survey. I think CRSPR technology has a bright future and support its further develop and use on food crops.

Overall I think crisper is a nice technology but will not save the world from food insecurity. I also worry that eventually more regulations will come and for crops that are sold on international markets/trade, the logistics of edited crops becomes more difficult.

Hello, USA and Canada are lumped together as "North America", but these two countries have very different approaches when it comes to the regulation of plants with novel traits. Based on this, participants from the US or Canada may answer some of the questions in this survey very differently. I am interested in the results of this study. My e-mail address is.

I am an applied researcher and extension specialist for wine grape producers. The wine grape industry in the west coast and much of Europe are very resistant to new technologies such as improved varieties and GMO's, making it hard to use CRISPR technology. Most wine grape regions are using unimproved plant material (Vitis vinifera), yet they want to grow more organic and biodynamic, with fewer to no sprays, yet they do not want improved plant materials and want to stick with the varieties they have, which have high disease susceptibility. This is the specific challenge with this cropping system.

Took well longer than 5-7 minutes

First, as a plant breeder, I have always found that there is way more genetic variation in crops for the traits I am interested in than I can effectively deal with, and don't need to create additional variation. In addition, 90% of the variation I work with is quantitative, while gene editing acts on qualitative traits.Such a technology is of limited value to me. Secondly, for some crops the barrier to transformation previously and gene editing currently, has been a lack of efficient regeneration systems. This is true for the main crop (common bean) with which I work, where many attempts at transformation/regeneration have failed. This will continue to be a barrier until either regeneration systems are established, or researchers find a way to do gene editing on whole organisms. Third, the organic community regards CRISPR as a genetic engineering technology. It has been declared such in the EU and the NOSB is considering rule changes to the NOP that would declare the same in the US. As such, gene edited cultivars could not be used in organic production. Organic agriculture is currently growing at about 8% per year and is now on the radar of multinational companies as a market to which they need to pay attention. The organic community regards genetic engineering as an excluded method because of the values and principles they have articulated. Practitioners of conventional agriculture do not have a philosophical basis for the technologies that are used, and until this happens, there will continue to be a wide chasm between the two. As biological scientists, we are unfamiliar and uncomfortable dealing with philosophical issues about our work, but these are the types of questions that need to be considered to understand the reluctance of many people to accept genetic engineering. Fourth, I think gene editing technologies will be dominated by large multinational companies who have deep pockets and maintain strong patent portfolios. Gene editing will be used for traits that benefit the corporation bottom line and not for traits that benefit stakeholders. If overused as transformation technology has been, we will see similar problems to the herbicide and insect resistance that has developed in major field crops.

In Canada, CRISPR as well as traditional mutagenesis breeding modifications are considered as PNT (Plants with a Novel Trait) and must undergo the same regulatory oversight as other genetically modified plants. In the US CRISPR is considered the same as traditional mutagenesis, and does not have the same regulatory requirements. So it is misleading to include both Canada and US together in your survey.

CRISPR supposes enough information is available about target genes; this is usually NOT the case. Therefore, CRISPR application requires considerable preliminary research to become effective; even with multi-CRISPR, the number of target genes that can be modified is limited, in the case of polygenic traits.

A major opportunity not mentioned in this survey involves the use of genome editing as a way to test hypotheses about the phenotypic consequences of specific forms of genetic variation, rather than as a pathway to product development or variety release. Once valuable variants have been identified, breeders can use genomics to search for germplasm carrying those variants (in landraces, wild relatives, germplasm collections, etc) and then use traditional crossing and selection to introduce them into elite varieties of crops, thus avoiding the regulatory challenges. This will take more time, but will enable plant breeders around the world to more effectively utilize naturally existing genetic variation in their programs. Genome editing is both a research tool and a breeding tool, and we can expect that the regulatory landscape will be very slow to change, but genetic and biological knowledge will continue to evolve very quickly, underscoring breeding efforts even if not directly employed in variety development.

In rice it is not so much acceptance in North America, foreign markets make the most impact on acceptance.

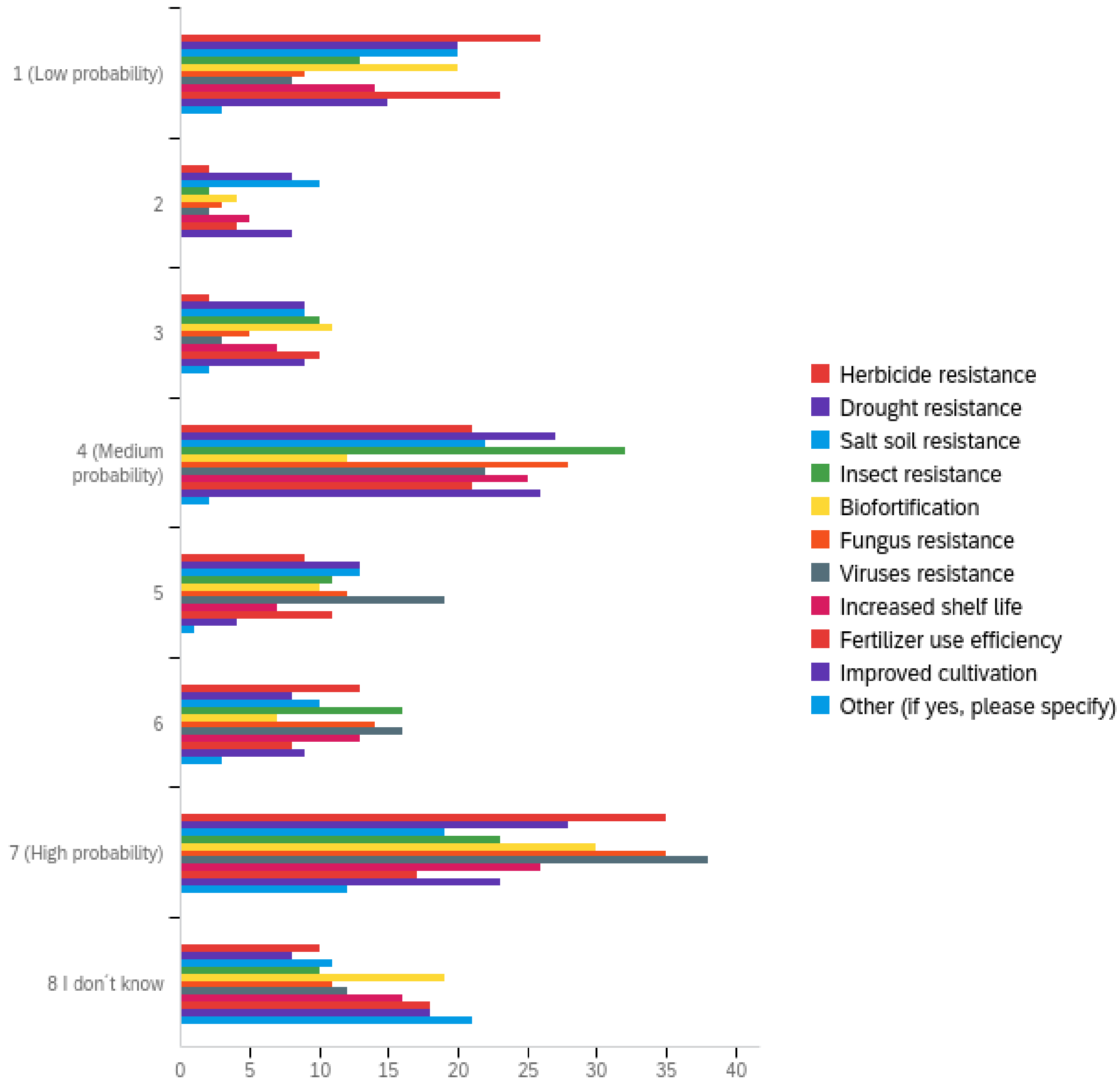
Survey was interested but did appear to be a bit biased relative to how questions were posed. One aspect not covered is the issue relative to ownership of the CRISP patented technology- researchers can use it for free, but to license it everyone must be able to afford to license to commercialize it- so there is and will be a major gap between R&D for the regions you asked about and actual commercializations and licenses. That is the most serious gap for the non- major crops. Seed companies working on fruits, vegetables, herbs, indigenous/traditional crops- the non main international commodities will face a herculean uphill battle to recoup licensing costs allowing it to move into the commercial realm. That is not captured by your survey- those details. Surveying research community should result in predictable/anticipated results. In anycase, do send me the final survey- and I will circulate this to colleagues and wish you the best in this research question which presumably will be used to generate more federal interest in supporting this important new technology.

None

I am sorry I left so much unanswered but tge questions are not related to my research field. You might want to remove my answers from your pool. This was much more focused on agriculture than general plant biology.

Not relevant to my work

Q39 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in Asia? Rate each on a scale from 1 to 7. Note: 116ultinatio development and implementation in this context means that the corresponding function can 116ultinationa be developed for and applied to multiple crops grown in the region.

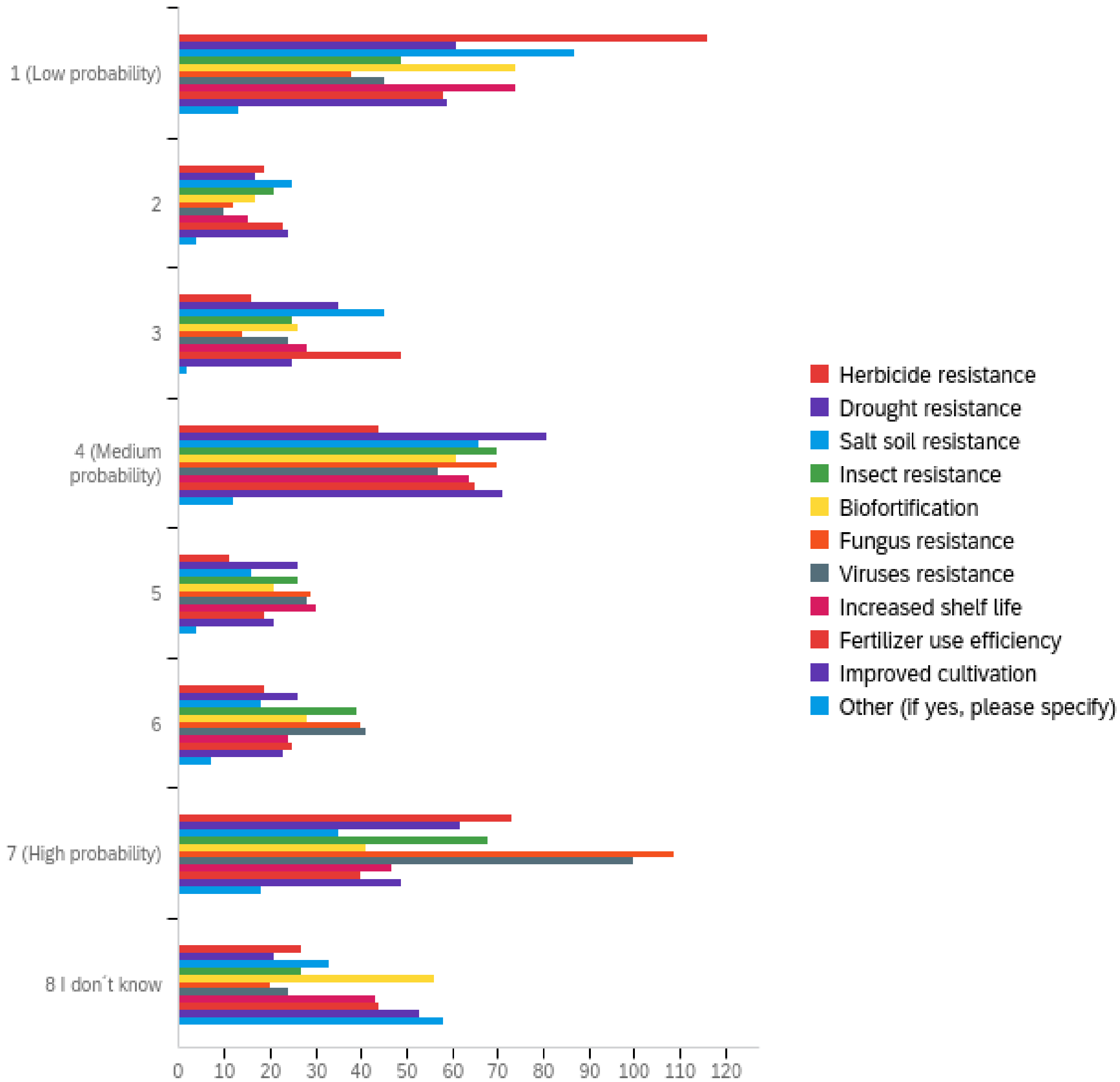


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	23.00	30.00	26.81	2.44	5.95	118
2	Drought resistance	23.00	30.00	26.50	2.26	5.09	121
3	Salt soil resistance	23.00	30.00	26.39	2.32	5.36	114
4	Insect resistance	23.00	30.00	26.85	2.05	4.22	117
5	Biofortification	23.00	30.00	26.98	2.51	6.28	113

6	Fungus resistance	23.00	30.00	27.29	1.99	3.95	117
7	Viruses resistance	23.00	30.00	27.52	1.88	3.53	120
8	Increased shelf life	23.00	30.00	27.03	2.27	5.16	113
9	Fertilizer use efficiency	23.00	30.00	26.56	2.47	6.09	112
10	Improved cultivation	23.00	30.00	26.83	2.38	5.66	112
11	Other (if yes, please specify)	23.00	30.00	28.64	2.02	4.10	44

#	Question	1 (Low probability)		2		3		4 (Medium probability)		5		6		7 (High probability)		8 I don´t know		Total
1	Herbicide resistance	22.03%	26	1.69%	2	1.69%	2	17.80%	21	7.63%	9	11.02%	13	29.66%	35	8.47%	10	118
2	Drought resistance	16.53%	20	6.61%	8	7.44%	9	22.31%	27	10.74%	13	6.61%	8	23.14%	28	6.61%	8	121
3	Salt soil resistance	17.54%	20	8.77%	10	7.89%	9	19.30%	22	11.40%	13	8.77%	10	16.67%	19	9.65%	11	114
4	Insect resistance	11.11%	13	1.71%	2	8.55%	10	27.35%	32	9.40%	11	13.68%	16	19.66%	23	8.55%	10	117
5	Biofortification	17.70%	20	3.54%	4	9.73%	11	10.62%	12	8.85%	10	6.19%	7	26.55%	30	16.81%	19	113
6	Fungus resistance	7.69%	9	2.56%	3	4.27%	5	23.93%	28	10.26%	12	11.97%	14	29.91%	35	9.40%	11	117
7	Viruses resistance	6.67%	8	1.67%	2	2.50%	3	18.33%	22	15.83%	19	13.33%	16	31.67%	38	10.00%	12	120
8	Increased shelf life	12.39%	14	4.42%	5	6.19%	7	22.12%	25	6.19%	7	11.50%	13	23.01%	26	14.16%	16	113
9	Fertilizer use efficiency	20.54%	23	3.57%	4	8.93%	10	18.75%	21	9.82%	11	7.14%	8	15.18%	17	16.07%	18	112
10	Improved cultivation	13.39%	15	7.14%	8	8.04%	9	23.21%	26	3.57%	4	8.04%	9	20.54%	23	16.07%	18	112
11	Other (if yes, please specify)	6.82%	3	0.00%	0	4.55%	2	4.55%	2	2.27%	1	6.82%	3	27.27%	12	47.73%	21	44

Q38 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in Europe? Rate each on a scale from 1 to 7. Note: 118ultinatio development and implementation in this context means that the corresponding function can 118ultinationa be developed for and applied to multiple crops grown in the region.

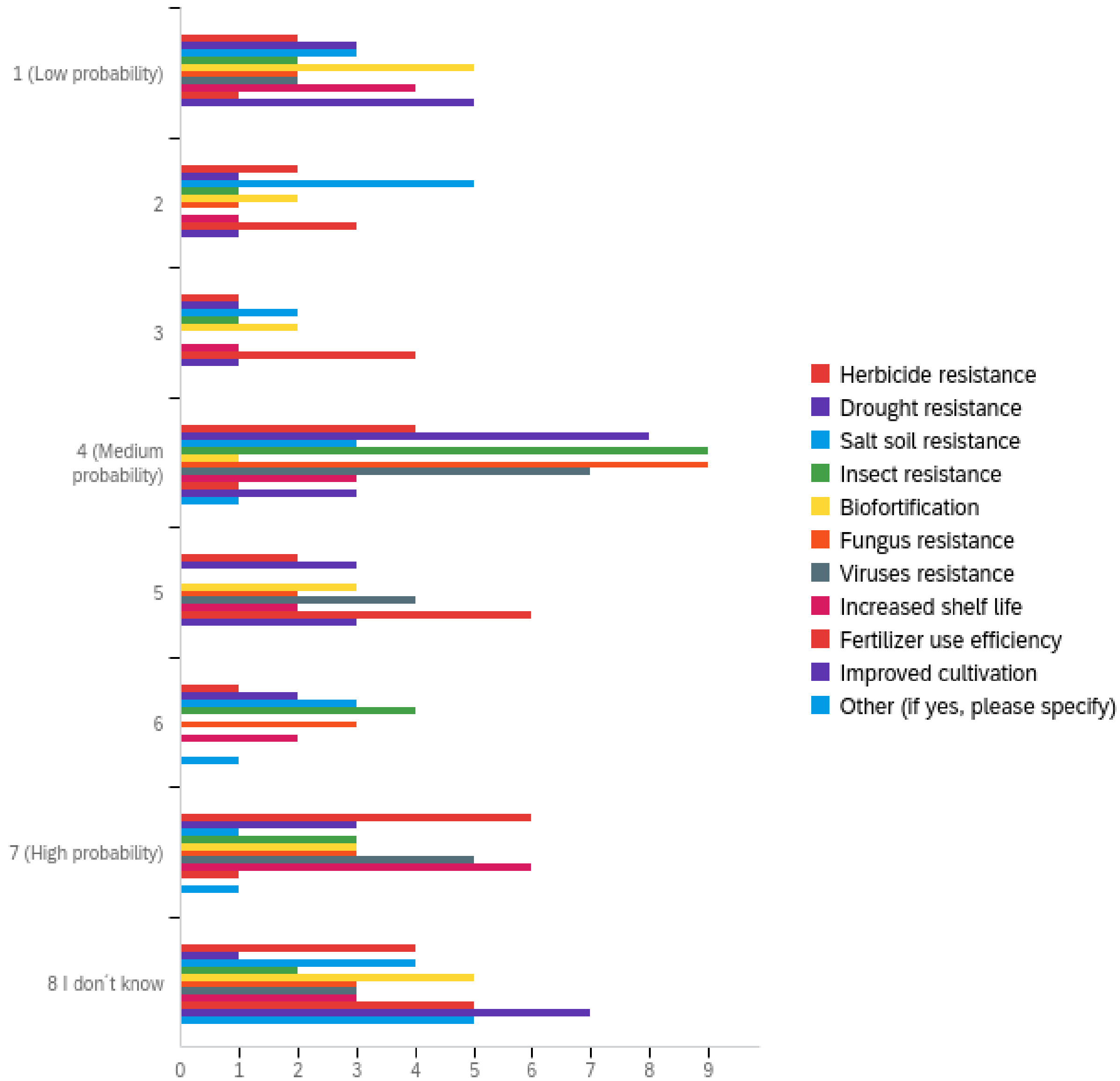


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	30.00	37.00	32.92	2.67	7.11	325
2	Drought resistance	30.00	37.00	33.29	2.24	5.01	329
3	Salt soil resistance	30.00	37.00	32.79	2.38	5.68	325
4	Insect resistance	30.00	37.00	33.62	2.25	5.08	325
5	Biofortification	30.00	37.00	33.44	2.54	6.47	324

6	Fungus resistance	30.00	37.00	34.10	2.12	4.50	332
7	Viruses resistance	30.00	37.00	33.99	2.22	4.92	329
8	Increased shelf life	30.00	37.00	33.34	2.45	6.01	325
9	Fertilizer use efficiency	30.00	37.00	33.30	2.37	5.63	323
10	Improved cultivation	30.00	37.00	33.54	2.45	6.03	325
11	Other (if yes, please specify)	30.00	37.00	35.16	2.45	5.98	118

#	Question	1 (Low probability)		2		3		4 (Medium probability)		5		6		7 (High probability)		8 I don´t know		Total
1	Herbicide resistance	35.69%	116	5.85%	19	4.92%	16	13.54%	44	3.38%	11	5.85%	19	22.46%	73	8.31%	27	325
2	Drought resistance	18.54%	61	5.17%	17	10.64%	35	24.62%	81	7.90%	26	7.90%	26	18.84%	62	6.38%	21	329
3	Salt soil resistance	26.77%	87	7.69%	25	13.85%	45	20.31%	66	4.92%	16	5.54%	18	10.77%	35	10.15%	33	325
4	Insect resistance	15.08%	49	6.46%	21	7.69%	25	21.54%	70	8.00%	26	12.00%	39	20.92%	68	8.31%	27	325
5	Biofortification	22.84%	74	5.25%	17	8.02%	26	18.83%	61	6.48%	21	8.64%	28	12.65%	41	17.28%	56	324
6	Fungus resistance	11.45%	38	3.61%	12	4.22%	14	21.08%	70	8.73%	29	12.05%	40	32.83%	109	6.02%	20	332
7	Viruses resistance	13.68%	45	3.04%	10	7.29%	24	17.33%	57	8.51%	28	12.46%	41	30.40%	100	7.29%	24	329
8	Increased shelf life	22.77%	74	4.62%	15	8.62%	28	19.69%	64	9.23%	30	7.38%	24	14.46%	47	13.23%	43	325
9	Fertilizer use efficiency	17.96%	58	7.12%	23	15.17%	49	20.12%	65	5.88%	19	7.74%	25	12.38%	40	13.62%	44	323
10	Improved cultivation	18.15%	59	7.38%	24	7.69%	25	21.85%	71	6.46%	21	7.08%	23	15.08%	49	16.31%	53	325
11	Other (if yes, please specify)	11.02%	13	3.39%	4	1.69%	2	10.17%	12	3.39%	4	5.93%	7	15.25%	18	49.15%	58	118

Q37 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in Oceania? Rate each on a scale from 1 to 7. Note: 120ultinatio development and implementation in this context means that the corresponding function can 120ultinationa be developed for and applied to multiple crops grown in the region.

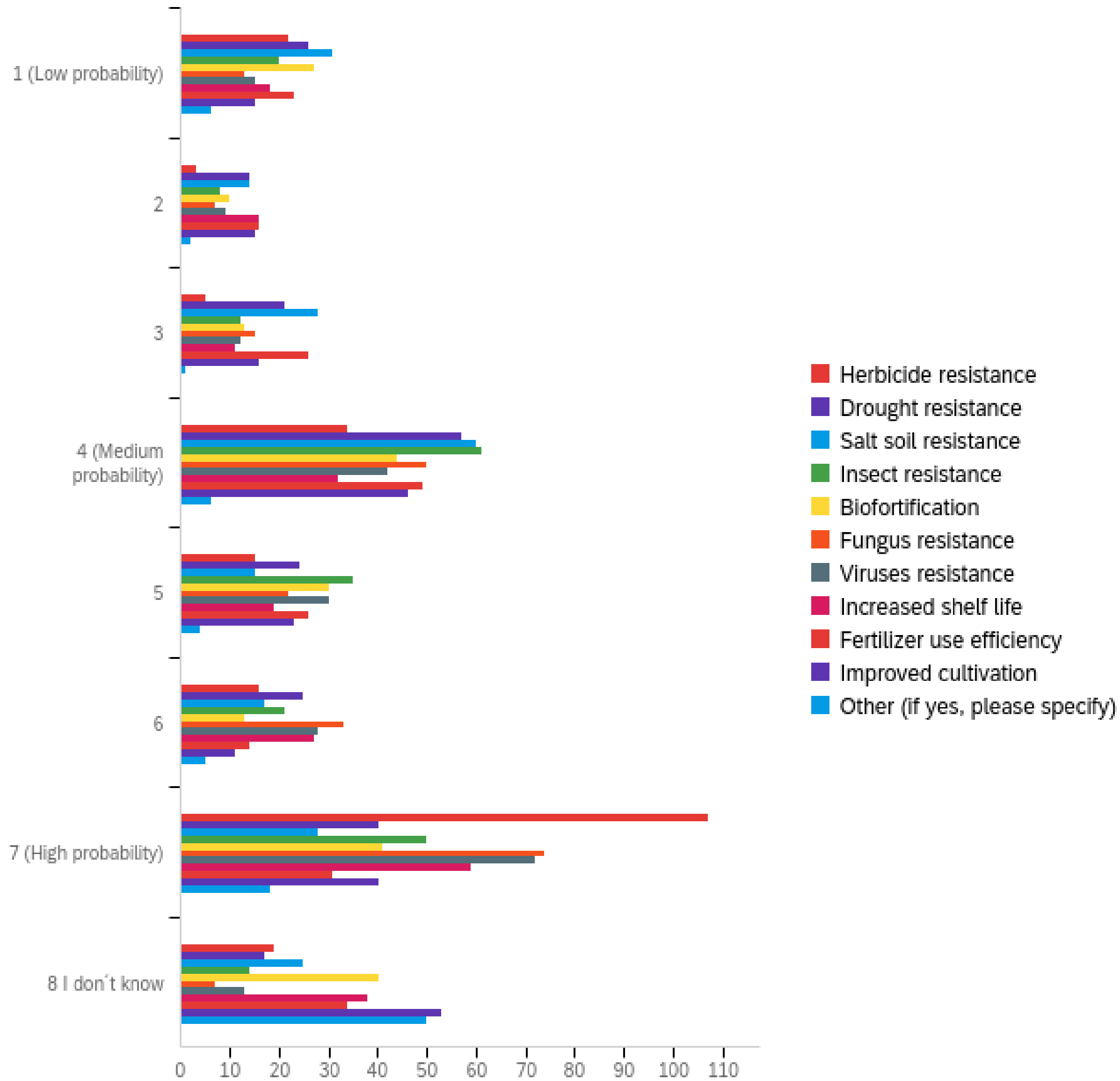


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	23.00	30.00	27.23	2.31	5.36	22
2	Drought resistance	23.00	30.00	26.36	1.94	3.78	22
3	Salt soil resistance	23.00	30.00	26.19	2.52	6.34	21
4	Insect resistance	23.00	30.00	26.73	1.98	3.93	22
5	Biofortification	23.00	30.00	26.52	2.75	7.58	21

6	Fungus resistance	23.00	30.00	26.91	2.00	3.99	23
7	Viruses resistance	23.00	30.00	27.19	2.01	4.06	21
8	Increased shelf life	23.00	30.00	26.95	2.46	6.04	22
9	Fertilizer use efficiency	23.00	30.00	26.76	2.27	5.13	21
10	Improved cultivation	23.00	30.00	26.65	2.80	7.83	20
11	Other (if yes, please specify)	26.00	30.00	29.13	1.36	1.86	8

#	Question	1 (Low probability)		2		3		4 (Medium probability)		5		6		7 (High probability)		8 I don´t know		Total
1	Herbicide resistance	9.09%	2	9.09%	2	4.55%	1	18.18%	4	9.09%	2	4.55%	1	27.27%	6	18.18%	4	22
2	Drought resistance	13.64%	3	4.55%	1	4.55%	1	36.36%	8	13.64%	3	9.09%	2	13.64%	3	4.55%	1	22
3	Salt soil resistance	14.29%	3	23.81%	5	9.52%	2	14.29%	3	0.00%	0	14.29%	3	4.76%	1	19.05%	4	21
4	Insect resistance	9.09%	2	4.55%	1	4.55%	1	40.91%	9	0.00%	0	18.18%	4	13.64%	3	9.09%	2	22
5	Biofortification	23.81%	5	9.52%	2	9.52%	2	4.76%	1	14.29%	3	0.00%	0	14.29%	3	23.81%	5	21
6	Fungus resistance	8.70%	2	4.35%	1	0.00%	0	39.13%	9	8.70%	2	13.04%	3	13.04%	3	13.04%	3	23
7	Viruses resistance	9.52%	2	0.00%	0	0.00%	0	33.33%	7	19.05%	4	0.00%	0	23.81%	5	14.29%	3	21
8	Increased shelf life	18.18%	4	4.55%	1	4.55%	1	13.64%	3	9.09%	2	9.09%	2	27.27%	6	13.64%	3	22
9	Fertilizer use efficiency	4.76%	1	14.29%	3	19.05%	4	4.76%	1	28.57%	6	0.00%	0	4.76%	1	23.81%	5	21
10	Improved cultivation	25.00%	5	5.00%	1	5.00%	1	15.00%	3	15.00%	3	0.00%	0	0.00%	0	35.00%	7	20
11	Other (if yes, please specify)	0.00%	0	0.00%	0	0.00%	0	12.50%	1	0.00%	0	12.50%	1	12.50%	1	62.50%	5	8

Q36 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in North America? Rate each on a scale from 1 to 7. Note: 122ultinatio development and implementation in this context means that the corresponding function can 122ultinationa be developed for and applied to multiple crops grown in the region.

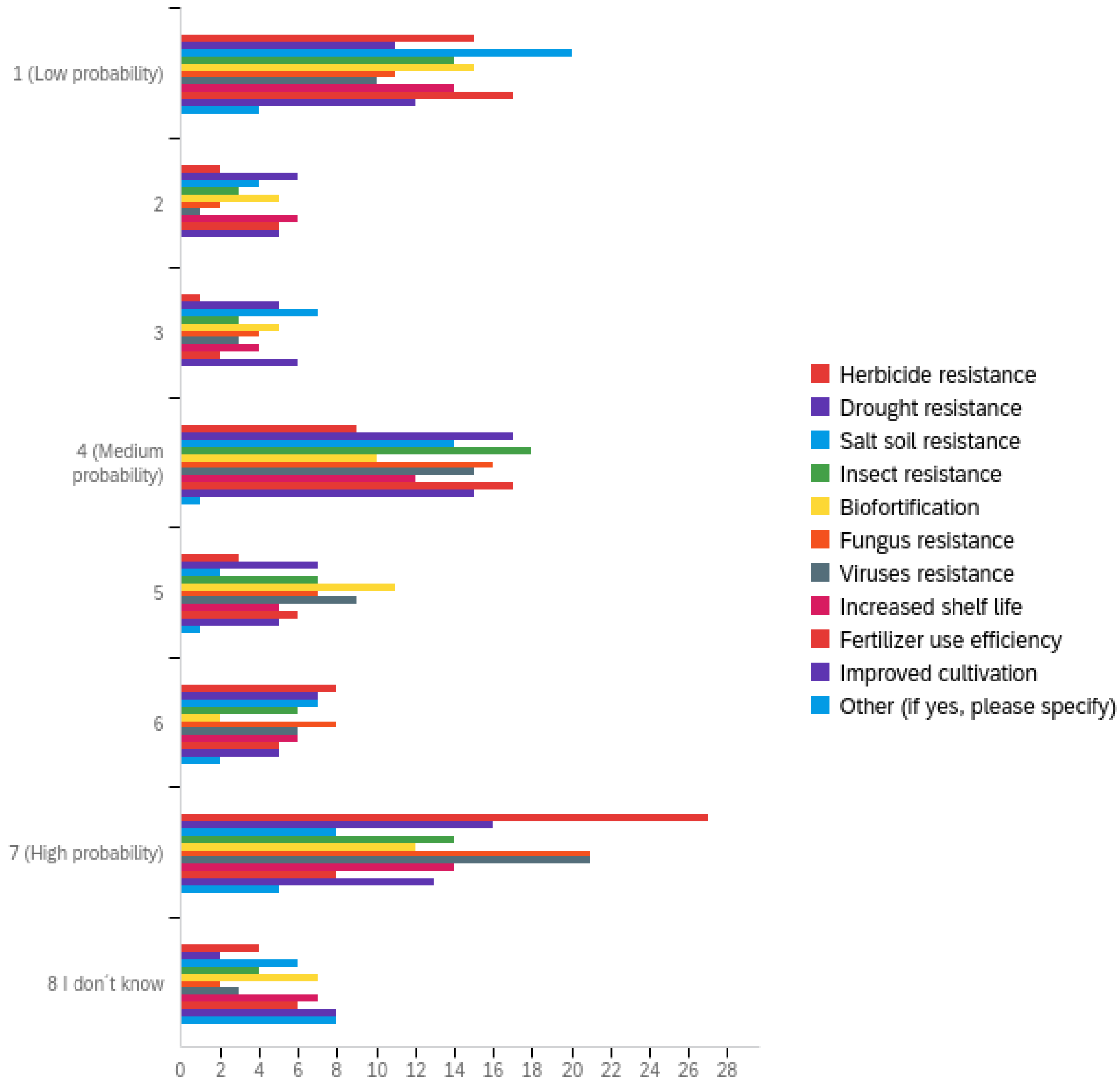


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	23.00	30.00	27.66	2.08	4.31	221
2	Drought resistance	23.00	30.00	26.60	2.10	4.40	224
3	Salt soil resistance	23.00	30.00	26.39	2.21	4.89	218
4	Insect resistance	23.00	30.00	26.88	1.96	3.82	221
5	Biofortification	23.00	30.00	27.03	2.30	5.30	218

6	Fungus resistance	23.00	30.00	27.22	1.86	3.45	221
7	Viruses resistance	23.00	30.00	27.26	1.94	3.75	221
8	Increased shelf life	23.00	30.00	27.39	2.22	4.91	220
9	Fertilizer use efficiency	23.00	30.00	26.71	2.23	4.98	219
10	Improved cultivation	23.00	30.00	27.31	2.25	5.08	219
11	Other (if yes, please specify)	23.00	30.00	28.66	2.08	4.31	92

#	Question	1 (Low probability)		2		3		4 (Medium probability)		5		6		7 (High probability)		8 I don´t know		Total
1	Herbicide resistance	9.95%	22	1.36%	3	2.26%	5	15.38%	34	6.79%	15	7.24%	16	48.42%	107	8.60%	19	221
2	Drought resistance	11.61%	26	6.25%	14	9.38%	21	25.45%	57	10.71%	24	11.16%	25	17.86%	40	7.59%	17	224
3	Salt soil resistance	14.22%	31	6.42%	14	12.84%	28	27.52%	60	6.88%	15	7.80%	17	12.84%	28	11.47%	25	218
4	Insect resistance	9.05%	20	3.62%	8	5.43%	12	27.60%	61	15.84%	35	9.50%	21	22.62%	50	6.33%	14	221
5	Biofortification	12.39%	27	4.59%	10	5.96%	13	20.18%	44	13.76%	30	5.96%	13	18.81%	41	18.35%	40	218
6	Fungus resistance	5.88%	13	3.17%	7	6.79%	15	22.62%	50	9.95%	22	14.93%	33	33.48%	74	3.17%	7	221
7	Viruses resistance	6.79%	15	4.07%	9	5.43%	12	19.00%	42	13.57%	30	12.67%	28	32.58%	72	5.88%	13	221
8	Increased shelf life	8.18%	18	7.27%	16	5.00%	11	14.55%	32	8.64%	19	12.27%	27	26.82%	59	17.27%	38	220
9	Fertilizer use efficiency	10.50%	23	7.31%	16	11.87%	26	22.37%	49	11.87%	26	6.39%	14	14.16%	31	15.53%	34	219
10	Improved cultivation	6.85%	15	6.85%	15	7.31%	16	21.00%	46	10.50%	23	5.02%	11	18.26%	40	24.20%	53	219
11	Other (if yes, please specify)	6.52%	6	2.17%	2	1.09%	1	6.52%	6	4.35%	4	5.43%	5	19.57%	18	54.35%	50	92

Q35 – Given your research activities, how do you rate the probability of successful development and implementation of the following possible functions of the CRISPR gene editing technology in South America? Rate each on a scale from 1 to 7. Note: 124ultinatio development and implementation in this context means that the corresponding function can 124ultinationa be developed for and applied to multiple crops grown in the region.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Herbicide resistance	37.00	44.00	40.96	2.48	6.13	69
2	Drought resistance	37.00	44.00	40.38	2.15	4.63	71
3	Salt soil resistance	37.00	44.00	39.84	2.42	5.87	68
4	Insect resistance	37.00	44.00	40.38	2.26	5.10	69
5	Biofortification	37.00	44.00	40.28	2.42	5.87	67

6	Fungus resistance	37.00	44.00	40.75	2.16	4.67	71
7	Viruses resistance	37.00	44.00	40.90	2.14	4.59	68
8	Increased shelf life	37.00	44.00	40.43	2.45	6.01	68
9	Fertilizer use efficiency	37.00	44.00	40.02	2.36	5.59	66
10	Improved cultivation	37.00	44.00	40.49	2.37	5.61	69
11	Other (if yes, please specify)	37.00	44.00	41.90	2.60	6.75	21

#	Question	1 (Low probability)		2		3		4 (Medium probability)		5		6		7 (High probability)		8 I don´t know		Total
1	Herbicide resistance	21.74%	15	2.90%	2	1.45%	1	13.04%	9	4.35%	3	11.59%	8	39.13%	27	5.80%	4	69
2	Drought resistance	15.49%	11	8.45%	6	7.04%	5	23.94%	17	9.86%	7	9.86%	7	22.54%	16	2.82%	2	71
3	Salt soil resistance	29.41%	20	5.88%	4	10.29%	7	20.59%	14	2.94%	2	10.29%	7	11.76%	8	8.82%	6	68
4	Insect resistance	20.29%	14	4.35%	3	4.35%	3	26.09%	18	10.14%	7	8.70%	6	20.29%	14	5.80%	4	69
5	Biofortification	22.39%	15	7.46%	5	7.46%	5	14.93%	10	16.42%	11	2.99%	2	17.91%	12	10.45%	7	67
6	Fungus resistance	15.49%	11	2.82%	2	5.63%	4	22.54%	16	9.86%	7	11.27%	8	29.58%	21	2.82%	2	71
7	Viruses resistance	14.71%	10	1.47%	1	4.41%	3	22.06%	15	13.24%	9	8.82%	6	30.88%	21	4.41%	3	68
8	Increased shelf life	20.59%	14	8.82%	6	5.88%	4	17.65%	12	7.35%	5	8.82%	6	20.59%	14	10.29%	7	68
9	Fertilizer use efficiency	25.76%	17	7.58%	5	3.03%	2	25.76%	17	9.09%	6	7.58%	5	12.12%	8	9.09%	6	66
10	Improved cultivation	17.39%	12	7.25%	5	8.70%	6	21.74%	15	7.25%	5	7.25%	5	18.84%	13	11.59%	8	69
11	Other (if yes, please specify)	19.05%	4	0.00%	0	0.00%	0	4.76%	1	4.76%	1	9.52%	2	23.81%	5	38.10%	8	21

Q53 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in Asia? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.90	1.92	3.70	92
2	Reduced environmental damage in agricultural production	1.00	7.00	4.20	2.09	4.38	91
3	Increased nutritional value in crops	1.00	7.00	4.05	1.82	3.31	92
4	Increased producer profits	1.00	7.00	4.30	1.90	3.61	90
5	Increased yields	1.00	7.00	4.11	1.87	3.50	96
6	Reduced yield variability	1.00	7.00	4.03	1.83	3.37	87
7	Other (if yes, please specify)	1.00	7.00	3.48	2.55	6.51	23

Q53_8_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
none
Initial stage
consumer benefit
resistance to disease
small farmers
reduced post harvest loss
Reduce chemicals
depends on the crop
increased emphasis on hybrid crops

Q52 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in Europe? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.33	1.93	3.71	295
2	Reduced environmental damage in agricultural production	1.00	7.00	4.18	1.91	3.65	294
3	Increased nutritional value in crops	1.00	7.00	3.91	1.99	3.96	293
4	Increased producer profits	1.00	7.00	3.95	2.00	3.98	291
5	Increased yields	1.00	7.00	4.33	2.02	4.08	293
6	Reduced yield variability	1.00	7.00	4.09	2.03	4.13	288
7	Other (if yes, please specify)	1.00	7.00	2.93	2.12	4.51	41

Q52_8_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
speed of breeding
new traits
Increased consumer choice
reduced post harvest loss
??
127ultinati diversity
I am very optimistic about CRISPR but I don’t want to give rate
Disease resistances
no
No
climate change resilience
Reduce chemicals
new color varieties
this ‘other ‘ questions bother me a lot!
Resistances
depends on the crop

Resistance against pests and diseases
Increased food safety
development speed
no
Monocultural practices, which is not the best, most sustainable way to cultivate crops, but which is the most widespread
Better use of ressources
reduced food waste
storage
speeding up the breeding process

Q51 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in Oceania? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.53	2.15	4.60	17
2	Reduced environmental damage in agricultural production	1.00	7.00	5.00	1.88	3.53	17
3	Increased nutritional value in crops	1.00	7.00	3.35	2.06	4.23	17
4	Increased producer profits	1.00	7.00	4.24	1.99	3.94	17
5	Increased yields	2.00	7.00	4.47	1.75	3.07	17
6	Reduced yield variability	1.00	7.00	3.88	2.00	3.99	17
7	Other (if yes, please specify)	1.00	6.00	3.20	2.32	5.36	5

Q51_8_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
Reduced barriers to trade
flexibility in agronomic practices
reduced post harvest loss

Q50 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in North America? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.25	1.82	3.33	186
2	Reduced environmental damage in agricultural production	1.00	7.00	4.03	1.97	3.88	189
3	Increased nutritional value in crops	1.00	7.00	4.12	1.89	3.59	185
4	Increased producer profits	1.00	7.00	4.14	1.90	3.62	185
5	Increased yields	1.00	7.00	4.39	1.97	3.87	187
6	Reduced yield variability	1.00	7.00	4.11	2.07	4.29	183
7	Other (if yes, please specify)	1.00	7.00	2.76	1.99	3.96	46

Q50_8_TEXT – Other (if yes, please specify)

Other (if yes, please specify) – Text
Plant stress
consumer product quality
seed company increased profits
improved human and animal health
Value added traits
health
reduced post harvest loss
increased fittness
Breakthroughs in fundamental plant sciences
fruit quality
Reduce chemicals
reduction in tractor traffic for pest and disease management
depends on the crop
improved abiotic stress tolerance
no

disease resistance
reduced pesticide usage
Seed companies
Improved organic or biodynamic production
Increased profits for multinational companies
Ornamental traits
increase disease resistance

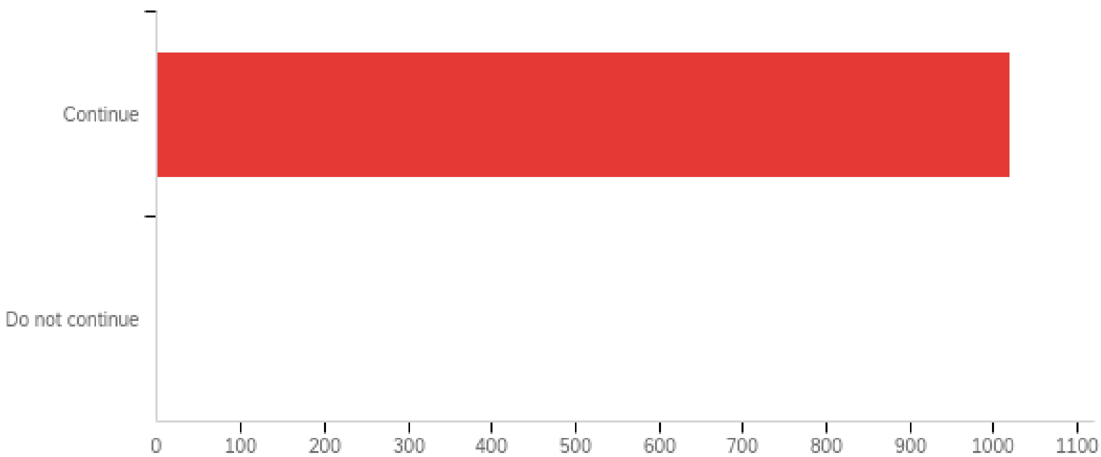
Q49 – What are (or will be) the major beneficiaries of CRISPR gene editing adoption in South America? Rate each option on a scale from 1 to 7.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.65	1.91	3.65	48
2	Reduced environmental damage in agricultural production	1.00	7.00	3.75	1.91	3.65	48
3	Increased nutritional value in crops	1.00	7.00	3.46	1.78	3.16	48
4	Increased producer profits	2.00	7.00	4.50	1.87	3.50	48
5	Increased yields	1.00	7.00	4.48	2.06	4.25	48
6	Reduced yield variability	1.00	7.00	4.46	2.01	4.04	48
7	Other (if yes, please specify)	1.00	7.00	3.00	2.28	5.20	10

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Reduced food insecurity	1.00	7.00	3.65	1.91	3.65	48
2	Reduced environmental damage in agricultural production	1.00	7.00	3.75	1.91	3.65	48
3	Increased nutritional value in crops	1.00	7.00	3.46	1.78	3.16	48
4	Increased producer profits	2.00	7.00	4.50	1.87	3.50	48
5	Increased yields	1.00	7.00	4.48	2.06	4.25	48
6	Reduced yield variability	1.00	7.00	4.46	2.01	4.04	48
7	Other (if yes, please specify)	1.00	7.00	3.00	2.28	5.20	10

#	Question	1 (No beneficiary)		4 (Medium beneficiary)		7 (Major beneficiary)		2		3		5		6		Total
1	Reduced food insecurity	8.33%	4	27.08%	13	25.00%	12	8.33%	4	6.25%	3	12.50%	6	12.50%	6	48
2	Reduced environmental damage in agricultural production	6.25%	3	25.00%	12	33.33%	16	0.00%	0	4.17%	2	20.83%	10	10.42%	5	48
3	Increased nutritional value in crops	8.33%	4	31.25%	15	22.92%	11	8.33%	4	8.33%	4	14.58%	7	6.25%	3	48
4	Increased producer profits	0.00%	0	20.83%	10	20.83%	10	6.25%	3	10.42%	5	22.92%	11	18.75%	9	48
5	Increased yields	2.08%	1	20.83%	10	27.08%	13	0.00%	0	2.08%	1	22.92%	11	25.00%	12	48
6	Reduced yield variability	4.17%	2	16.67%	8	25.00%	12	4.17%	2	6.25%	3	20.83%	10	22.92%	11	48
7	Other (if yes, please specify)	40.00%	4	20.00%	2	10.00%	1	0.00%	0	0.00%	0	20.00%	2	10.00%	1	10

Q58 – By continuing and completing this survey, I am agreeing for my anonymous responses to be used in this research.

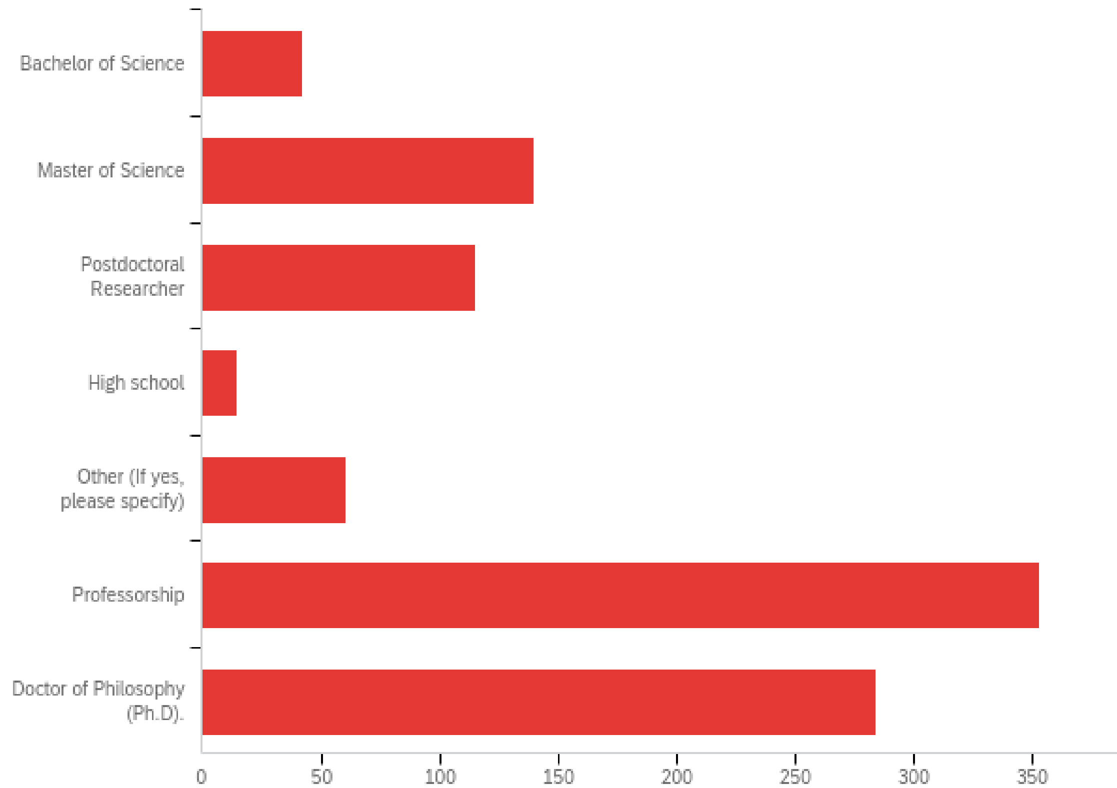


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	By continuing and completing this survey, I am agreeing for my anonymous responses to be used in this research.	1.00	2.00	1.00	0.03	0.00	1021

#	Answer	%	Count
1	Continue	99.90%	1020
2	Do not continue	0.10%	1

	Total	100%	1021

Q41 – Please indicate your academic level:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Please indicate your academic level: - Selected Choice	1.00	7.00	5.09	1.96	3.85	1010

#	Answer	%	Count
1	Bachelor of Science	4.16%	42
2	Master of Science	13.86%	140
3	Postdoctoral Researcher	11.39%	115
4	High school	1.49%	15
5	Other (If yes, please specify)	6.04%	61
6	Professorship	34.95%	353
7	Doctor of Philosophy (Ph.D).	28.12%	284
	Total	100%	1010

Q41_5_TEXT – Other (If yes, please specify)

Other (If yes, please specify) – Text
Research scientist
Research scientist
Director and Professor
Researcher
Head Centre for Plant Genome Engineering at HHU Dusseldorf/Germany
PhD, Institutional Team Leader
US Federal Government Researcher
Licenciatura (equivalent to MSc)
Private Sector Scientist
Ph.D of biology
Associate Professor
Researcher
Scientist
Director if research and education center
Vice President for Research
Bachelor of Arts
Senior scientist
Industry scientist
Group Leader
Master of Management
Unit Head
Scientist
Senior Researcher
director of center
Associate professor
Senior Researcher

Doctor of Business Management
Senior Scientist
autodidact
Research Scientist
PhD student
Group leader, not professor
Senior Scientist (PhD, MSc hons))
Lab head
Group Leader (PI)
PhD Plant Genetics Ongoing
Honours degree and currently completing MSc.
Group leader
Senior research and group leader in a research institute
Honours degree
Assistant Professor
Agronomist
head of laboratory (with PhD degree)
Ph.D. and habilitation
Research lead
Federal Scientist
plant breeder
Senior research scientist
Researcher
Scientist (Molecular breeder)
Research manager
MBA
BSc Agronomy
Director

Bachelor of Science Honours
head of research institute
Team Leader Breeding
MBA
Research Scientist
Government Scientist
Retired professor

Q56 – Please indicate how much of your time (in %) you are active in the fundamental and/or applied plant sciences:

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Distribution fundamental/applied plant sciences	0.00	100.00	66.12	28.51	812.71	888

Q55 – The focus in my role as plant scientist is mainly on (please specify using the sliders, in %, adding to a total of 100%):

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Yield improvement	0.00	100.00	44.05	28.39	806.04	741
2	Stress resilience (biotic/abiotic)	0.00	100.00	49.98	30.10	906.15	773
3	Nutritional alteration/improvement	0.00	100.00	30.21	27.77	771.10	500
4	Mineral uptake (e.g. fertilizer efficiency)	0.00	100.00	26.16	27.03	730.65	344
5	Storage (e.g. shelf life)	0.00	100.00	27.90	28.18	793.89	336
6	Other (please specify)	0.00	100.00	56.11	33.83	1144.22	300

Q55_4_TEXT – Other (please specify)

Other (please specify) – Text
Specialized metabolism
regulatory policy
Safety
Plant reproduction
basic research
development, cell biology
Rice grain quality
crop protection
pest control
Governance
Quality improvement
Recombination improvement
Basic science
Gene editing and DNA repair
crop ecology (interactions with farm management and wild biodiversity)
No
risk assessment, regulation

development and hormone signaling
Organelle Molecular Genetics
storage of genetic resources
Ionising radiation effects
Editing optimization
Methods for in planta delivery of genome editing components
Phytopathology
genome
Plant pathogens
Environmental sustainability
basic research on hormonal regulation of plant development
sex determination
flowering time
plant molecular farming
plant microbe interactions
Technical development
reproduction and recombination
Teaching
137ultinatio of new technologies, teaching
plant microbe interaction
molecular farming
photothermal adaptability
Biotechnology
Fruit Development
transgene detection
Food Safety
Reproductive biology
Optimize GMO procedure

Economic/commercial focus
ability to for nodule symbiosis
Plant fertility
Disease diagnostics
risk assessment
Breedin methodolgy
fungal infections
gene expression
Plant Science Dissemination
Breeding
technological quality
bioactive metabolites
plant virus interactions
genome editing
fish scientist
other quality: compactness and postharvest
Developmental biology
biosafety
ornamentals
Enabling technologies
basic research
Biomass alteration/improvement
Regulation
genetic engineering/dna repair/recombination
Evolution / Natural Variation
Interaction with management techniques, eg crop rotation
technology
Policy Matters

Optimizing plant breeding schemes
Seed type (size, colour and culinary)
National University of Agriculture, Benin
Plant reproductive barriers
nitrogen-fixing root nodule symbioses
Bio-energy purposes
Ecology
Cotton fiber quality
Basic science (how plant hormones work and what the do)
Computational methods
Developmental biology
Quality for Youngplant producer
Fruit quality
water use efficiency
basic research
New leads
ornamental value, production yield
plant symbiosis
Pest resistance
plant architecture
0
100% Plant Molecular Genetics
Regulatory
Evolution and systematics
systematics
Diagnostics
flower number/colour/quality, plant habit, etc
Cell walls, wood processability (lignin)

morphology
seed production and quality improvement
Genome analysis
Root Growth Behavior and Mechanotansduction
Production of secondary metabolites
phenotyping
specific combine ability of parental lines in breeding program
secondary metabolism
Ecology
Fundamental plant systems biology (investigating genetic regulation of programmed cell death), with little to no emphasis on applied approaches
Production and up-regulation of medicinal compounds
Organic agriculture / Conservation agriculture / Composting
farming systems
systematics
Fundamental research on regulation of growth and development
Understanding the forces underlying genetic variation
-
Disease resistance
understanding functions and structures, basic research
Characterization of molecular mechanisms of plant development
nutrition
Metabolic engineering
Yield/Quality Modelling
Ecology and conservation
water
plant population biology
seed developmental mechanisms
diagnostics and biosecurity

ecological adaptation
alternative environments (space flight, Martian surface, zero-energy greenhouses and contained environments
Education, publishing, science communication
Secondary metabolites
Regulation
SEED QUALITY CONTROL
seed quality
circularity
general consumer preferences of crop varieties
Improve breeding
plant habit
Mechanical harvesting
research management
Biomass quality
Deconstruction
gene regulation
Evolutionary genomics
Not a scientist right now. Regulatory Affairs Manager
fundamental research
plant-associated microbial interactions
sustainability
quantitative genetics/prediction
germplasm conservation
Soil management
GIS
good houseplant
Cultivar adaptability to microclimates.
Seminars and meetings

secondary metabolite enhancement
Technology development
Market traits, maturity, lodging
integrated pest management
Biosafety and risk assessment
fundamental developmental and cell biology
Germination
breeding, hormonal signalling, cell biology, stress response etc.
Flowering and Phenology
developmental biology
food, nutrition and molecular interactions, dietary fibres
Taste
plant development and reproduction
architecture
Disease resistance
Insect resistance
New Leads
disease management
sustainability
technology development
biofuels
plant protection
diversity
Plant size and lodging tolerance
fruit quality
Genetic diversity and evolution
disease resistance
genome engineering

Technology development
disease resistance
develop project proposals 143ultin plant sciences, train plant scientists and create awareness about the importance of plant sciences for sustainable agriculture
protection of plant
climate change
biotech solutions
Physical traits such as colour and height
I, Transcriptional Regulation
quality
Developing new cultivars
disease and pest resitance
valuable molecules produced by plants
flower colour
Phenotypic traits
new varieties
Season extension
quality
fertility
Flowering time
Pest resistance
basic research
plant reproduction/breeding
GENETIC RESOURCES
Adaptation to organic management
Technology adoption
Flavor/eating quality
Milling and grain quality
Dissease Management and monitoring

quality
Statistics
communications
Technology improvement
biomass processing efficiency
Genomics
flavor
Ornamental value
Quality of flour
Industrial quality
outreach
new breeding technologies
woody biomass processing
Oil Quality
Innocuity
reproduction
Biomass properties
144ultinatio biological nitrogen fixation
Resistance to plant diseases
breeding
disease resistance
Developmental biology
Advising growers
Quality
Processability traits
amenability of the plant lignocellulosic biomass to processing into biofuels and bioproducts
Technology Optimization
research managemnt

plant development (basic research)
beneficial plant microbe interaction capacity
Photosynthesis
ecophysiology
raw materials (rubber contents)
Developmental biology
seed health
vegetable quality parameters
horticultural quality
Disease tolerance/resistance
plant development in general
general applications plant biotech, biosafety
genome 145ultinati, mutagenesis and evolution
Plant protection
Flowering time
Plant adaptation to seasonal change
Improvement of fruit quality
ornamental value
Plant development & evolution. Education, teaching
Plant development, cell biology
Plant development
Bread making quality
disease resistance
gxe interaction mainly on stress
Innovation management & compliance
Plant protection/resistance
Plant diseases and their management
Novel traits for consumer markets

Plant diseases
herbicide tolerance
virus
plant architecture
Development
Disease resistance
pest management
Breeding for organic systems
end-use quality
herbicide resistance
flavor
colonization by human bacterial pathogens
ornamental traits – flower/leaf color, bark, etc.
Food/feed safety
basic research in mutagenesis
Biofuels and bioproducts
25%rice quality milling chalk reduction etc
I am a diagnostician
Irrigation efficiency and runoff mitigation
End-use quality
disease resistance
Biodiversity
Pest management
grain quality

Q43 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in Asia:

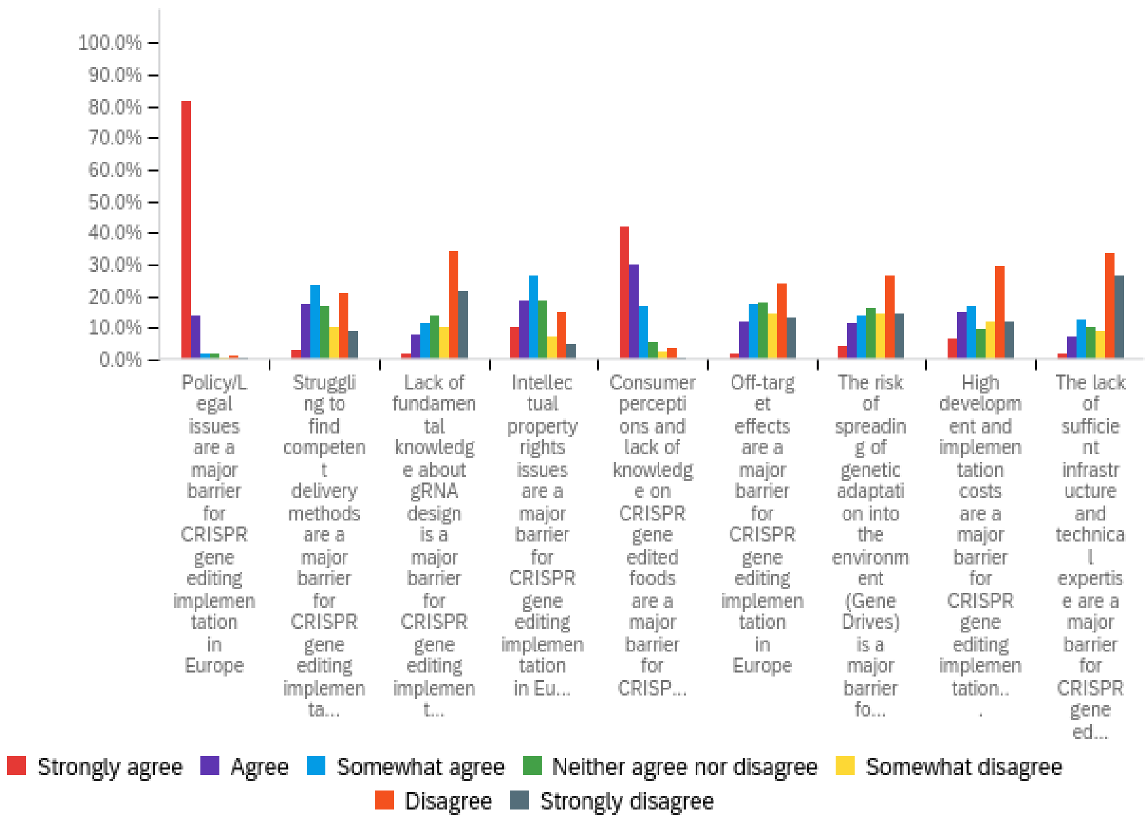
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	14.60	1.71	2.91	104
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.03	1.88	3.53	101
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.82	1.82	3.30	102
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.24	1.76	3.09	99
5	Consumer perceptions and lack of knowledge on CRISPR gene gene edited foods are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.02	1.63	2.65	101
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.24	1.85	3.43	101
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.02	1.73	2.98	100
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.69	1.83	3.35	100
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.22	1.88	3.55	103

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	14.60	1.71	2.91	104
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.03	1.88	3.53	101
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.82	1.82	3.30	102
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.24	1.76	3.09	99
5	Consumer perceptions and lack of knowledge on CRISPR gene gene edited foods are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.02	1.63	2.65	101
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.24	1.85	3.43	101
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.02	1.73	2.98	100
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	15.69	1.83	3.35	100
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Asia	13.00	19.00	16.22	1.88	3.55	103

#	Question	Strongly agree		Agree		Somewhat agree		Neither agree nor disagree		Somewhat disagree		Disagree		Strongly disagree		Total
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Asia	36.54%	38	22.12%	23	14.42%	15	11.54%	12	4.81%	5	8.65%	9	1.92%	2	104
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Asia	6.93%	7	21.78%	22	17.82%	18	11.88%	12	4.95%	5	29.70%	30	6.93%	7	101
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Asia	5.88%	6	6.86%	7	14.71%	15	13.73%	14	6.86%	7	34.31%	35	17.65%	18	102
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Asia	14.14%	14	29.29%	29	20.20%	20	13.13%	13	7.07%	7	10.10%	10	6.06%	6	99
5	Consumer perceptions and lack of knowledge on CRISPR gene gene edited foods are a major barrier for CRISPR gene editing implementation in Asia	16.83%	17	27.72%	28	26.73%	27	9.90%	10	5.94%	6	9.90%	10	2.97%	3	101
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Asia	7.92%	8	16.83%	17	12.87%	13	11.88%	12	14.85%	15	27.72%	28	7.92%	8	101
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Asia	8.00%	8	15.00%	15	19.00%	19	16.00%	16	12.00%	12	27.00%	27	3.00%	3	100
8	High development and implementatio	12.00%	12	18.00%	18	27.00%	27	6.00%	6	10.00%	10	23.00%	23	4.00%	4	100

	n costs are a major barrier for CRISPR gene editing implementation in Asia															
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Asia	7.77%	8	13.59 %	14	23.30%	24	6.80%	7	11.65%	12	26.21%	27	10.68%	11	103

Q44 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in Europe:



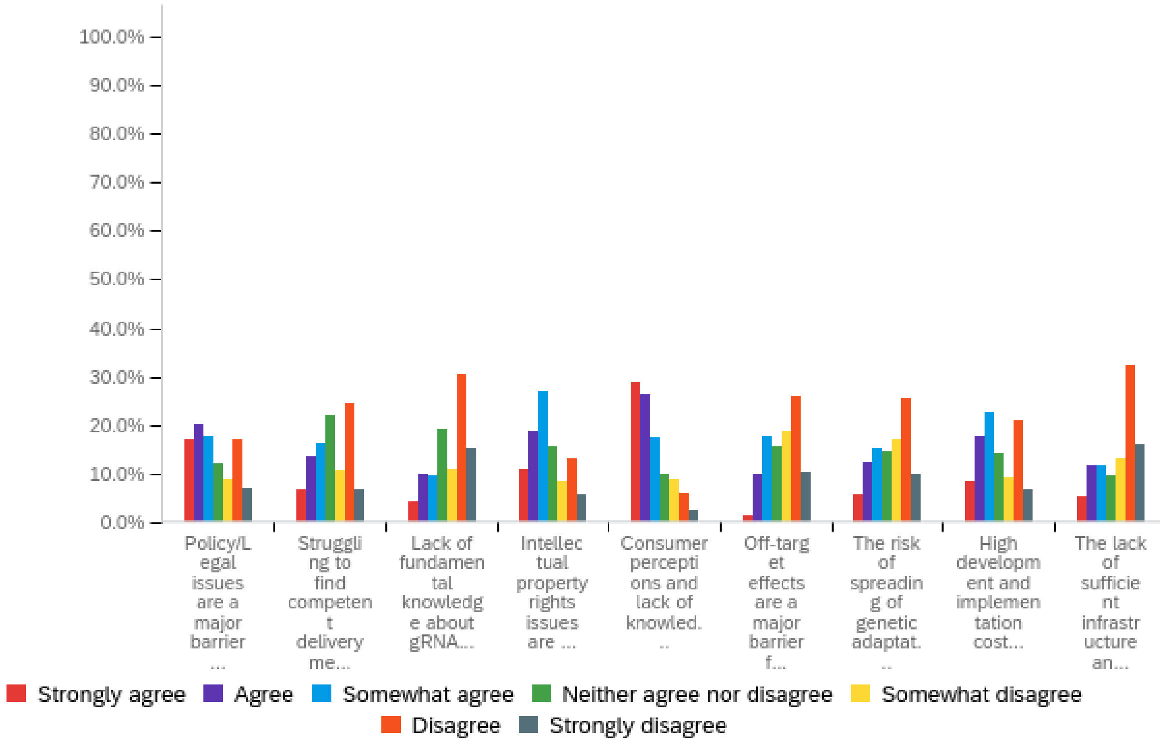
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	13.31	0.87	0.75	322
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	16.13	1.71	2.92	310
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	17.10	1.66	2.75	311
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	15.58	1.67	2.80	314

5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	14.09	1.31	1.70	316
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	16.55	1.66	2.76	310
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	16.60	1.75	3.08	313
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	16.40	1.88	3.52	312
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Europe	13.00	19.00	17.22	1.69	2.87	311

Q45 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in Oceania:

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in Oceania	13.00	18.00	14.75	1.67	2.79	20
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in Oceania	13.00	19.00	15.89	2.07	4.30	19
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in Oceania	13.00	19.00	17.40	1.71	2.94	20
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in Oceania	13.00	19.00	16.11	1.83	3.36	19
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in Oceania	13.00	18.00	14.79	1.64	2.69	19
6	Off-target effects are a major barrier for CRISPR gene editing implementation in Oceania	14.00	19.00	16.75	1.81	3.29	20
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in Oceania	13.00	18.00	16.05	1.69	2.85	20
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in Oceania	13.00	19.00	15.53	2.06	4.25	19
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in Oceania	13.00	19.00	16.80	2.16	4.66	20

Q46 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in North America:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	15.54	1.93	3.72	216
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	16.16	1.72	2.96	209
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	16.76	1.74	3.03	209
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	15.55	1.71	2.93	211
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	14.72	1.65	2.72	212
6	Off-target effects are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	16.60	1.58	2.50	212
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	16.41	1.75	3.06	212
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	15.87	1.79	3.22	210
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in North America	13.00	19.00	16.75	1.84	3.37	211

#	Question	Strongly agree		Agree		Somewhat agree		Neither agree nor disagree		Somewhat disagree		Disagree		Strongly disagree		Total
1	Policy/Legal issues are a	17.13%	37	20.37%	44	17.59%	38	12.04%	26	8.80%	19	17.13%	37	6.94%	15	216

	major barrier for CRISPR gene editing implementation in North America															
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in North America	6.70%	14	13.40%	28	16.27%	34	22.01%	46	10.53%	22	24.40%	51	6.70%	14	209
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in North America	4.31%	9	10.05%	21	9.57%	20	19.14%	40	11.00%	23	30.62%	64	15.31%	32	209
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in North America	10.90%	23	18.96%	40	27.01%	57	15.64%	33	8.53%	18	13.27%	28	5.69%	12	211
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in North America	28.77%	61	26.42%	56	17.45%	37	9.91%	21	8.96%	19	6.13%	13	2.36%	5	212
6	Off-target effects are a major barrier for CRISPR gene editing implementation in North America	1.42%	3	9.91%	21	17.92%	38	15.57%	33	18.87%	40	25.94%	55	10.38%	22	212
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in North America	5.66%	12	12.26%	26	15.09%	32	14.62%	31	16.98%	36	25.47%	54	9.91%	21	212
8	High development and implementation	8.57%	18	17.62%	37	22.86%	48	14.29%	30	9.05%	19	20.95%	44	6.67%	14	210

	costs are a major barrier for CRISPR gene editing implementation in North America															
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in North America	5.21%	11	11.85%	25	11.85%	25	9.48%	20	13.27%	28	32.23%	68	16.11%	34	211

Q47 – Given your research activities, please give your opinion about what the major barriers are that impede the large scale implementation of CRISPR gene editing in South America:

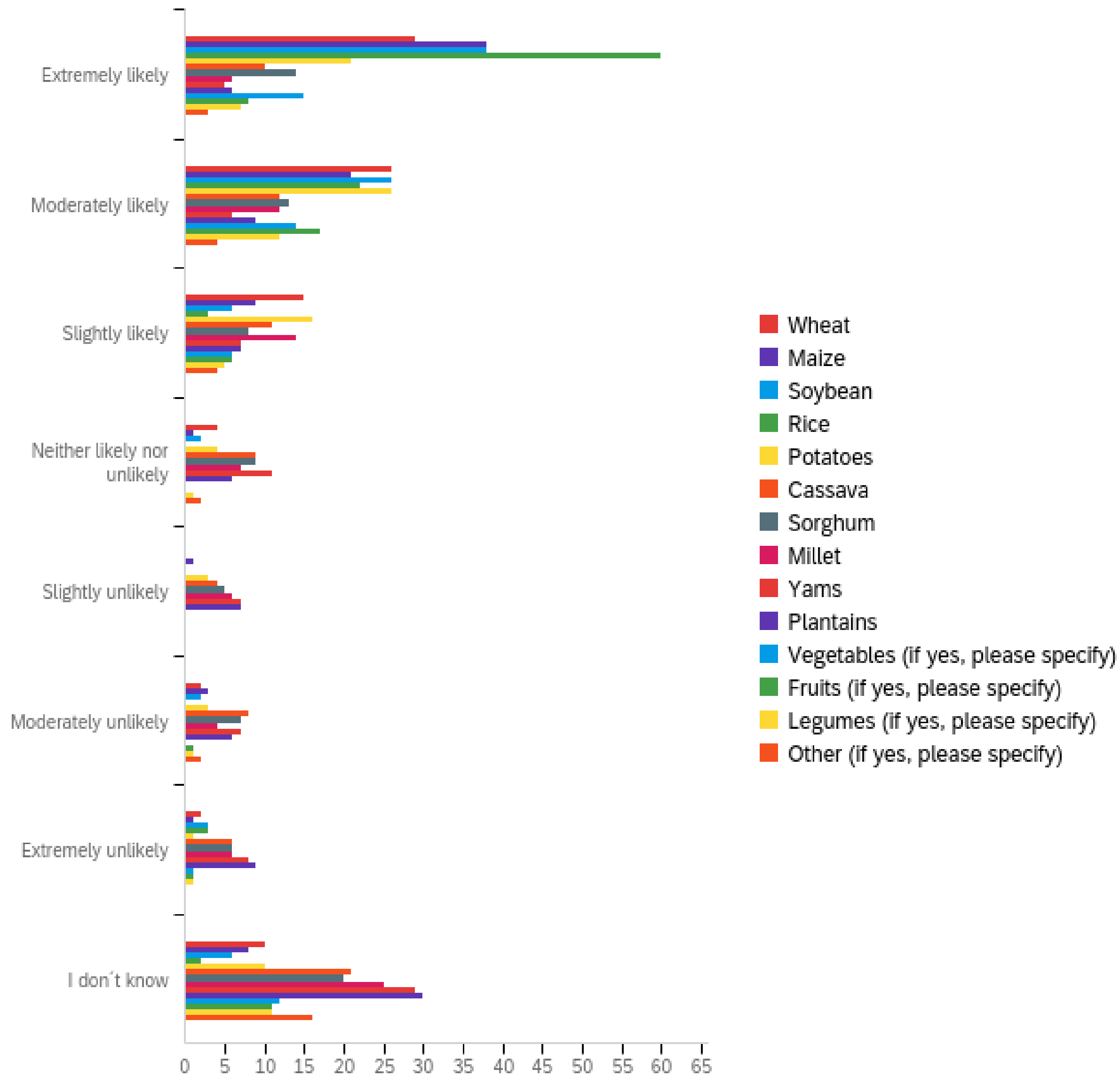
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.43	1.95	3.82	56
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.13	1.86	3.45	54
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.45	1.96	3.85	56
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.62	1.75	3.07	55
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	14.84	1.61	2.60	56
6	Off-target effects are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.80	1.72	2.96	55
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.42	1.87	3.51	57
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in South America</spa	13.00	19.00	15.23	1.89	3.57	56
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.81	2.01	4.05	57

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.43	1.95	3.82	56
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.13	1.86	3.45	54
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.45	1.96	3.85	56
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.62	1.75	3.07	55
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	14.84	1.61	2.60	56
6	Off-target effects are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.80	1.72	2.96	55
7	The risk of spreading of genetic adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	16.42	1.87	3.51	57
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in South America</spa	13.00	19.00	15.23	1.89	3.57	56
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in South America	13.00	19.00	15.81	2.01	4.05	57

#	Question	Strongly agree		Agree		Somewhat agree		Neither agree nor disagree		Somewhat disagree		Disagree		Strongly disagree		Total
1	Policy/Legal issues are a major barrier for CRISPR gene editing implementation in South America	17.86%	10	25.00%	14	14.29%	8	14.29%	8	3.57%	2	17.86%	10	7.14%	4	56
2	Struggling to find competent delivery methods are a major barrier for CRISPR gene editing implementation in South America	11.11%	6	11.11%	6	14.81%	8	22.22%	12	7.41%	4	24.07%	13	9.26%	5	54
3	Lack of fundamental knowledge about gRNA design is a major barrier for CRISPR gene editing implementation in South America	7.14%	4	14.29%	8	16.07%	9	14.29%	8	1.79%	1	30.36%	17	16.07%	9	56
4	Intellectual property rights issues are a major barrier for CRISPR gene editing implementation in South America	10.91%	6	21.82%	12	20.00%	11	14.55%	8	10.91%	6	18.18%	10	3.64%	2	55
5	Consumer perceptions and lack of knowledge on CRISPR gene edited foods are a major barrier for CRISPR gene editing implementation in South America	26.79%	15	17.86%	10	28.57%	16	8.93%	5	8.93%	5	7.14%	4	1.79%	1	56
6	Off-target effects are a major barrier for CRISPR gene editing implementation in South America	7.27%	4	5.45%	3	9.09%	5	14.55%	8	18.18%	10	32.73%	18	12.73%	7	55
7	The risk of spreading of genetic	7.02%	4	10.53%	6	19.30%	11	14.04%	8	10.53%	6	22.81%	13	15.79%	9	57

	adaptation into the environment (Gene Drives) is a major barrier for CRISPR gene editing implementation in South America															
8	High development and implementation costs are a major barrier for CRISPR gene editing implementation in South America</sp a	19.64%	11	25.00%	14	21.43%	12	7.14%	4	5.36%	3	16.07%	9	5.36%	3	56
9	The lack of sufficient infrastructure and technical expertise are a major barrier for CRISPR gene editing implementation in South America	12.28%	7	26.32%	15	14.04%	8	3.51%	2	10.53%	6	26.32%	15	7.02%	4	57

Q48 - What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in Asia? Rate each on a scale from 1 to 7.

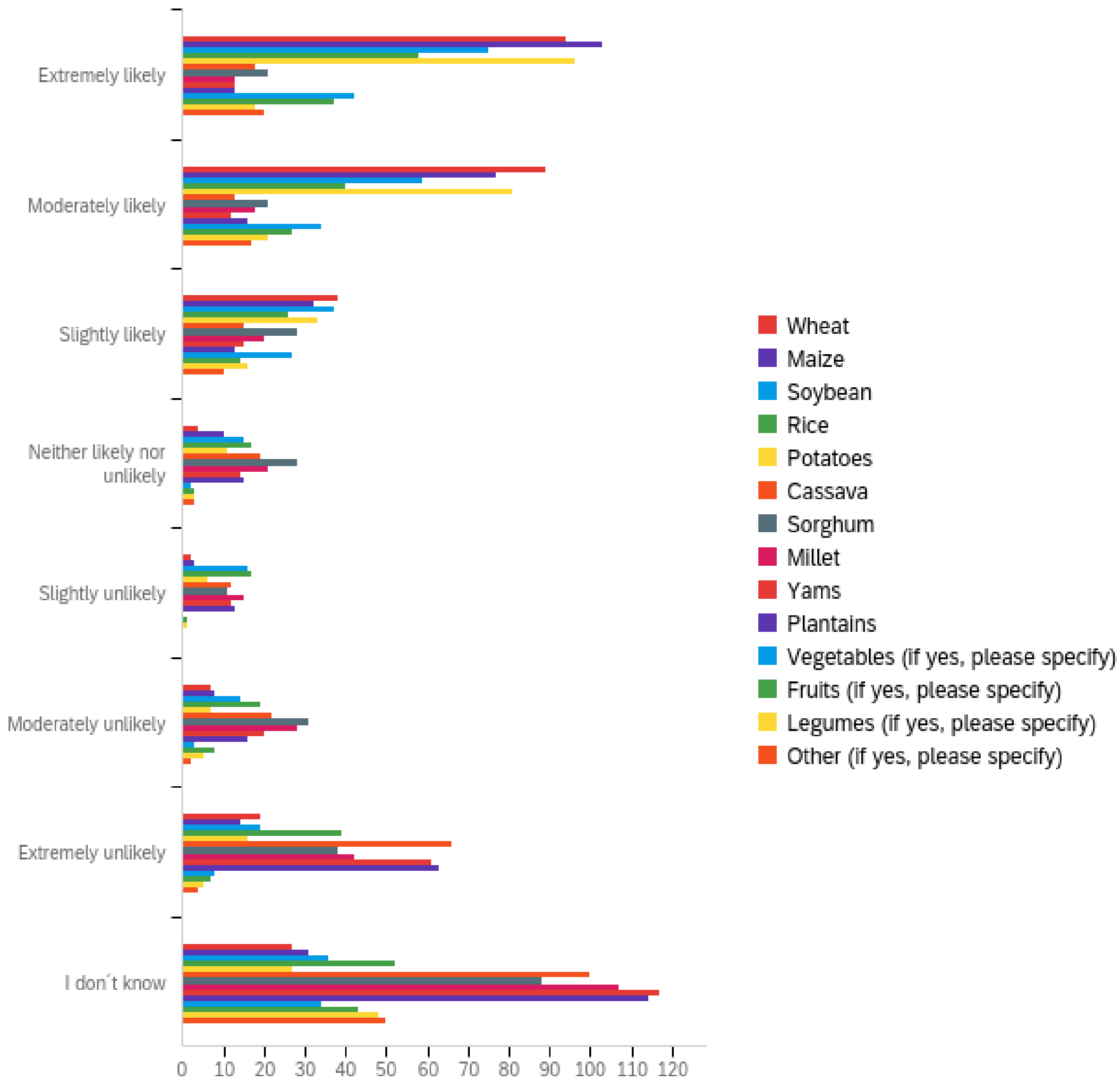


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	72.82	2.24	5.04	88
2	Maize	71.00	78.00	72.50	2.21	4.88	82
3	Soybean	71.00	78.00	72.37	2.09	4.38	83
4	Rice	71.00	78.00	71.67	1.49	2.22	90
5	Potatoes	71.00	78.00	73.06	2.23	4.98	84
6	Cassava	71.00	78.00	74.70	2.57	6.60	81

7	Sorghum	71.00	78.00	74.50	2.64	6.98	82
8	Millet	71.00	78.00	74.95	2.55	6.50	80
9	Yams	71.00	78.00	75.59	2.36	5.57	80
10	Plantains	71.00	78.00	75.54	2.50	6.25	80
11	Vegetables (if yes, please specify)	71.00	78.00	73.42	2.82	7.95	48
12	Fruits (if yes, please specify)	71.00	78.00	73.66	2.74	7.50	44
13	Legumes (if yes, please specify)	71.00	78.00	73.97	2.83	8.03	38
14	Other (if yes, please specify)	71.00	78.00	75.52	2.78	7.73	31

#	Question	Extremely likely		Moderately likely		Slightly likely		Neither likely nor unlikely		Slightly unlikely		Moderately unlikely		Extremely unlikely		I don´t know		Total
1	Wheat	32.95%	29	29.55%	26	17.05%	15	4.55%	4	0.00%	0	2.27%	2	2.27%	2	11.36%	10	88
2	Maize	46.34%	38	25.61%	21	10.98%	9	1.22%	1	1.22%	1	3.66%	3	1.22%	1	9.76%	8	82
3	Soybean	45.78%	38	31.33%	26	7.23%	6	2.41%	2	0.00%	0	2.41%	2	3.61%	3	7.23%	6	83
4	Rice	66.67%	60	24.44%	22	3.33%	3	0.00%	0	0.00%	0	0.00%	0	3.33%	3	2.22%	2	90
5	Potatoes	25.00%	21	30.95%	26	19.05%	16	4.76%	4	3.57%	3	3.57%	3	1.19%	1	11.90%	10	84
6	Cassava	12.35%	10	14.81%	12	13.58%	11	11.11%	9	4.94%	4	9.88%	8	7.41%	6	25.93%	21	81
7	Sorghum	17.07%	14	15.85%	13	9.76%	8	10.98%	9	6.10%	5	8.54%	7	7.32%	6	24.39%	20	82
8	Millet	7.50%	6	15.00%	12	17.50%	14	8.75%	7	7.50%	6	5.00%	4	7.50%	6	31.25%	25	80
9	Yams	6.25%	5	7.50%	6	8.75%	7	13.75%	11	8.75%	7	8.75%	7	10.00%	8	36.25%	29	80
10	Plantains	7.50%	6	11.25%	9	8.75%	7	7.50%	6	8.75%	7	7.50%	6	11.25%	9	37.50%	30	80
11	Vegetables (if yes, please specify)	31.25%	15	29.17%	14	12.50%	6	0.00%	0	0.00%	0	0.00%	0	2.08%	1	25.00%	12	48
12	Fruits (if yes, please specify)	18.18%	8	38.64%	17	13.64%	6	0.00%	0	0.00%	0	2.27%	1	2.27%	1	25.00%	11	44
13	Legumes (if yes, please specify)	18.42%	7	31.58%	12	13.16%	5	2.63%	1	0.00%	0	2.63%	1	2.63%	1	28.95%	11	38
14	Other (if yes, please specify)	9.68%	3	12.90%	4	12.90%	4	6.45%	2	0.00%	0	6.45%	2	0.00%	0	51.61%	16	31

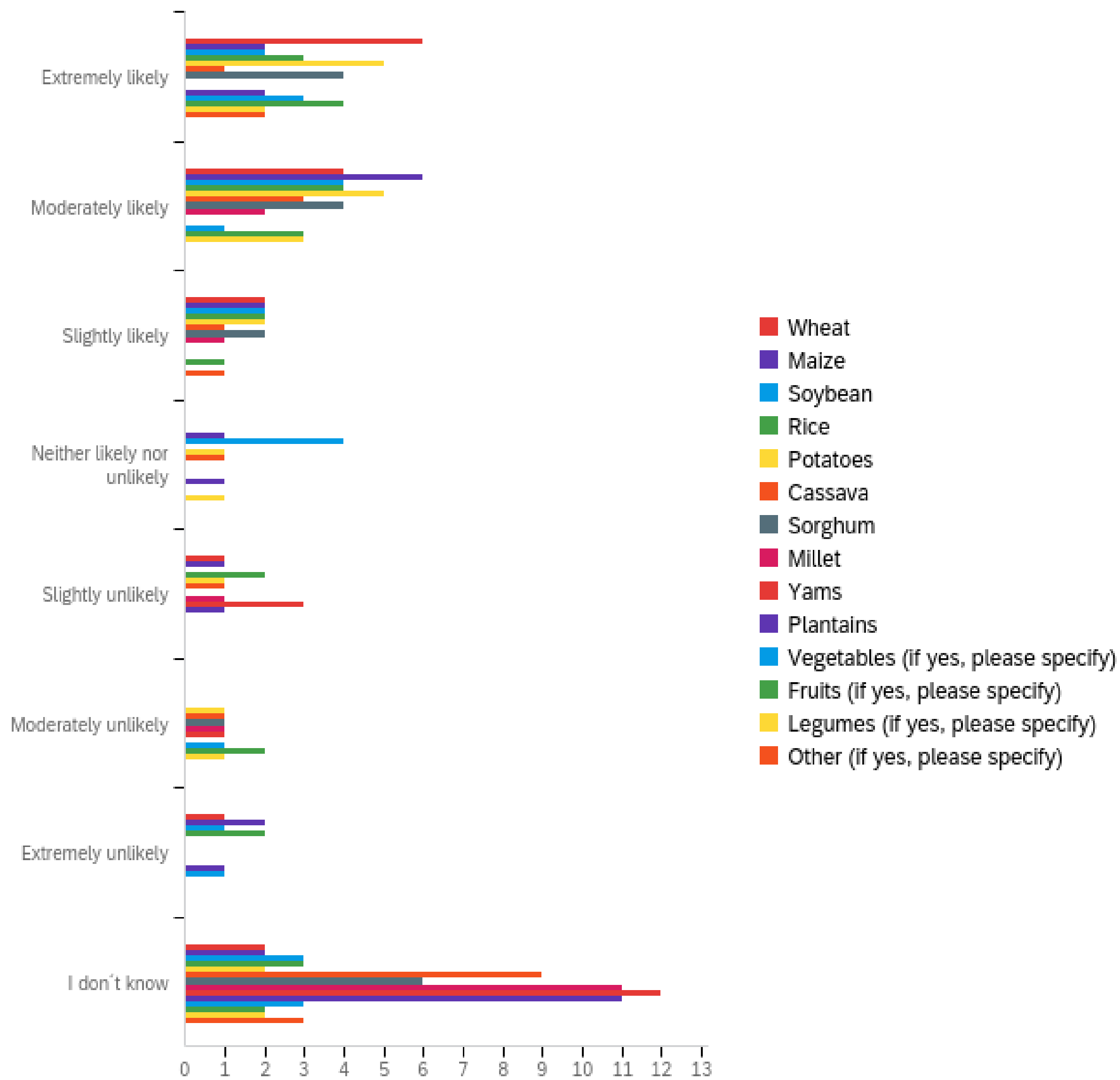
Q49 - What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technolog y in Europe? Rate each on a scale from 1 to 7.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	72.87	2.33	5.41	280
2	Maize	71.00	78.00	72.88	2.38	5.68	278
3	Soybean	71.00	78.00	73.50	2.50	6.27	271
4	Rice	71.00	78.00	74.37	2.70	7.26	268
5	Potatoes	71.00	78.00	72.89	2.32	5.38	277
6	Cassava	71.00	78.00	76.11	2.25	5.07	265
7	Sorghum	71.00	78.00	75.53	2.43	5.89	266
8	Millet	71.00	78.00	76.01	2.27	5.16	264
9	Yams	71.00	78.00	76.37	2.14	4.60	264
10	Plantains	71.00	78.00	76.30	2.19	4.81	263
11	Vegetables (if yes, please specify)	71.00	78.00	73.63	2.77	7.66	150
12	Fruits (if yes, please specify)	71.00	78.00	74.22	2.97	8.80	140
13	Legumes (if yes, please specify)	71.00	78.00	74.91	2.92	8.55	117
14	Other (if yes, please specify)	71.00	78.00	75.06	3.05	9.28	106

Q50 - What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in Oceania? Rate each on a scale from 1 to 7.

#	Question	Extremely likely		Moderately likely		Slightly likely		Neither likely nor unlikely		Slightly unlikely		Moderately unlikely		Extremely unlikely		I don´t know		Total
1	Wheat	33.57%	94	31.79%	89	13.57%	38	1.43%	4	0.71%	2	2.50%	7	6.79%	19	9.64%	27	280
2	Maize	37.05%	103	27.70%	77	11.51%	32	3.60%	10	1.08%	3	2.88%	8	5.04%	14	11.15%	31	278
3	Soybean	27.68%	75	21.77%	59	13.65%	37	5.54%	15	5.90%	16	5.17%	14	7.01%	19	13.28%	36	271
4	Rice	21.64%	58	14.93%	40	9.70%	26	6.34%	17	6.34%	17	7.09%	19	14.55%	39	19.40%	52	268
5	Potatoes	34.66%	96	29.24%	81	11.91%	33	3.97%	11	2.17%	6	2.53%	7	5.78%	16	9.75%	27	277
6	Cassava	6.79%	18	4.91%	13	5.66%	15	7.17%	19	4.53%	12	8.30%	22	24.91%	66	37.74%	100	265
7	Sorghum	7.89%	21	7.89%	21	10.53%	28	10.53%	28	4.14%	11	11.65%	31	14.29%	38	33.08%	88	266
8	Millet	4.92%	13	6.82%	18	7.58%	20	7.95%	21	5.68%	15	10.61%	28	15.91%	42	40.53%	107	264
9	Yams	4.92%	13	4.55%	12	5.68%	15	5.30%	14	4.55%	12	7.58%	20	23.11%	61	44.32%	117	264
10	Plantains	4.94%	13	6.08%	16	4.94%	13	5.70%	15	4.94%	13	6.08%	16	23.95%	63	43.35%	114	263
11	Vegetables (if yes, please specify)	28.00%	42	22.67%	34	18.00%	27	1.33%	2	0.00%	0	2.00%	3	5.33%	8	22.67%	34	150
12	Fruits (if yes, please specify)	26.43%	37	19.29%	27	10.00%	14	2.14%	3	0.71%	1	5.71%	8	5.00%	7	30.71%	43	140
13	Legumes (if yes, please specify)	15.38%	18	17.95%	21	13.68%	16	2.56%	3	0.85%	1	4.27%	5	4.27%	5	41.03%	48	117
14	Other (if yes, please specify)	18.87%	20	16.04%	17	9.43%	10	2.83%	3	0.00%	0	1.89%	2	3.77%	4	47.17%	50	106

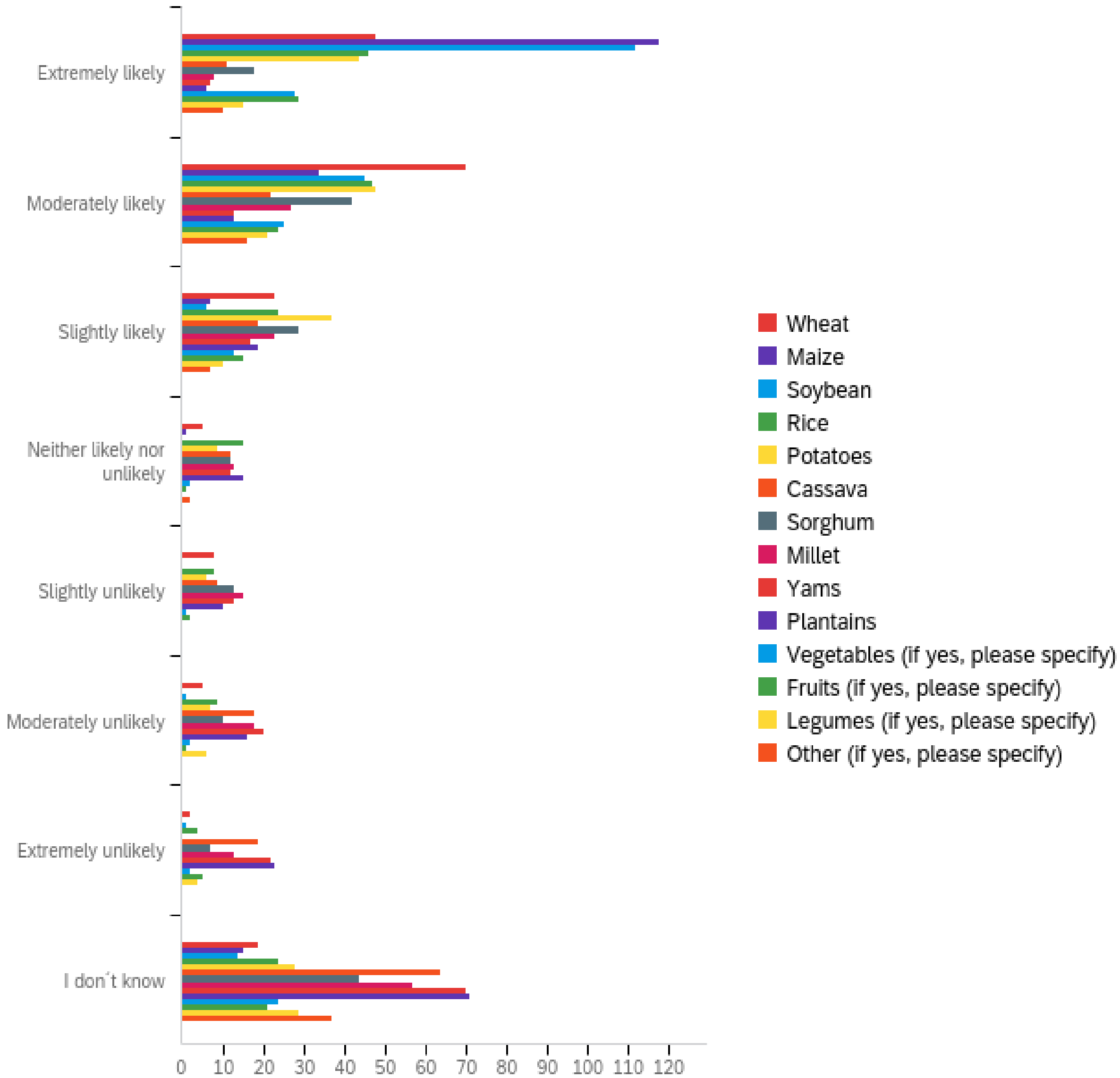


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	73.00	2.47	6.13	16
2	Maize	71.00	78.00	73.69	2.42	5.84	16
3	Soybean	71.00	78.00	73.94	2.41	5.81	16
4	Rice	71.00	78.00	74.06	2.66	7.06	16
5	Potatoes	71.00	78.00	73.06	2.29	5.23	17
6	Cassava	71.00	78.00	75.71	2.67	7.15	17
7	Sorghum	71.00	78.00	74.24	3.00	9.00	17

8	Millet	72.00	78.00	76.63	2.23	4.98	16
9	Yams	75.00	78.00	77.31	1.21	1.46	16
10	Plantains	71.00	78.00	76.63	2.42	5.86	16
11	Vegetables (if yes, please specify)	71.00	78.00	74.67	3.13	9.78	9
12	Fruits (if yes, please specify)	71.00	78.00	73.42	2.66	7.08	12
13	Legumes (if yes, please specify)	71.00	78.00	73.78	2.70	7.28	9
14	Other (if yes, please specify)	71.00	78.00	74.83	3.24	10.47	6

#	Question	Extremely likely		Moderately likely		Slightly likely		Neither likely nor unlikely		Slightly unlikely		Moderately unlikely		Extremely unlikely		I don´t know		Total
1	Wheat	37.50%	6	25.00%	4	12.50%	2	0.00%	0	6.25%	1	0.00%	0	6.25%	1	12.50%	2	16
2	Maize	12.50%	2	37.50%	6	12.50%	2	6.25%	1	6.25%	1	0.00%	0	12.50%	2	12.50%	2	16
3	Soybean	12.50%	2	25.00%	4	12.50%	2	25.00%	4	0.00%	0	0.00%	0	6.25%	1	18.75%	3	16
4	Rice	18.75%	3	25.00%	4	12.50%	2	0.00%	0	12.50%	2	0.00%	0	12.50%	2	18.75%	3	16
5	Potatoes	29.41%	5	29.41%	5	11.76%	2	5.88%	1	5.88%	1	5.88%	1	0.00%	0	11.76%	2	17
6	Cassava	5.88%	1	17.65%	3	5.88%	1	5.88%	1	5.88%	1	5.88%	1	0.00%	0	52.94%	9	17
7	Sorghum	23.53%	4	23.53%	4	11.76%	2	0.00%	0	0.00%	0	5.88%	1	0.00%	0	35.29%	6	17
8	Millet	0.00%	0	12.50%	2	6.25%	1	0.00%	0	6.25%	1	6.25%	1	0.00%	0	68.75%	11	16
9	Yams	0.00%	0	0.00%	0	0.00%	0	0.00%	0	18.75%	3	6.25%	1	0.00%	0	75.00%	12	16
10	Plantains	12.50%	2	0.00%	0	0.00%	0	6.25%	1	6.25%	1	0.00%	0	6.25%	1	68.75%	11	16
11	Vegetables (if yes, please specify)	33.33%	3	11.11%	1	0.00%	0	0.00%	0	0.00%	0	11.11%	1	11.11%	1	33.33%	3	9
12	Fruits (if yes, please specify)	33.33%	4	25.00%	3	8.33%	1	0.00%	0	0.00%	0	16.67%	2	0.00%	0	16.67%	2	12
13	Legumes (if yes, please specify)	22.22%	2	33.33%	3	0.00%	0	11.11%	1	0.00%	0	11.11%	1	0.00%	0	22.22%	2	9
14	Other (if yes, please specify)	33.33%	2	0.00%	0	16.67%	1	0.00%	0	0.00%	0	0.00%	0	0.00%	0	50.00%	3	6

Q51 - What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technolog y in North America? Rate each on a scale from 1 to 7.



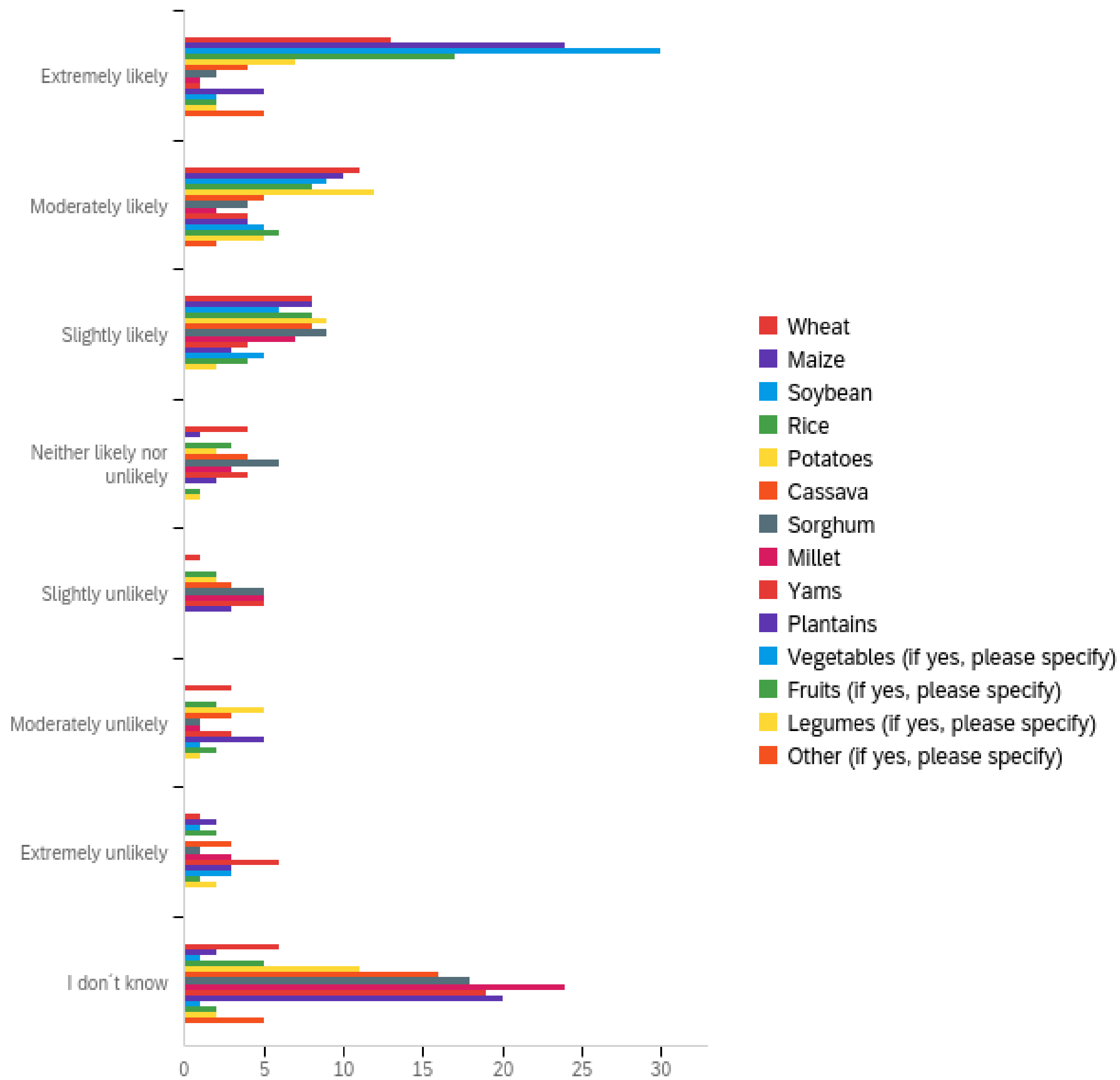
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	72.85	2.17	4.71	180
2	Maize	71.00	78.00	71.89	1.95	3.81	175
3	Soybean	71.00	78.00	71.93	1.92	3.70	179
4	Rice	71.00	78.00	73.31	2.38	5.68	177
5	Potatoes	71.00	78.00	73.26	2.37	5.63	179
6	Cassava	71.00	78.00	75.51	2.50	6.25	174

7	Sorghum	71.00	78.00	74.36	2.57	6.61	175
8	Millet	71.00	78.00	75.25	2.45	6.03	174
9	Yams	71.00	78.00	75.93	2.27	5.16	174
10	Plantains	71.00	78.00	75.92	2.29	5.23	173
11	Vegetables (if yes, please specify)	71.00	78.00	73.59	2.80	7.83	97
12	Fruits (if yes, please specify)	71.00	78.00	73.52	2.74	7.51	98
13	Legumes (if yes, please specify)	71.00	78.00	74.51	2.93	8.60	85
14	Other (if yes, please specify)	71.00	78.00	75.10	3.04	9.25	72

#	Question	Extremely likely		Moderately likely		Slightly likely		Neither likely nor unlikely		Slightly unlikely		Moderately unlikely		Extremely unlikely		I don´t know		Total
1	Wheat	26.67%	48	38.89%	70	12.78%	23	2.78%	5	4.44%	8	2.78%	5	1.11%	2	10.56%	19	180
2	Maize	67.43%	118	19.43%	34	4.00%	7	0.57%	1	0.00%	0	0.00%	0	0.00%	0	8.57%	15	175
3	Soybean	62.57%	112	25.14%	45	3.35%	6	0.00%	0	0.00%	0	0.56%	1	0.56%	1	7.82%	14	179
4	Rice	25.99%	46	26.55%	47	13.56%	24	8.47%	15	4.52%	8	5.08%	9	2.26%	4	13.56%	24	177
5	Potatoes	24.58%	44	26.82%	48	20.67%	37	5.03%	9	3.35%	6	3.91%	7	0.00%	0	15.64%	28	179
6	Cassava	6.32%	11	12.64%	22	10.92%	19	6.90%	12	5.17%	9	10.34%	18	10.92%	19	36.78%	64	174
7	Sorghum	10.29%	18	24.00%	42	16.57%	29	6.86%	12	7.43%	13	5.71%	10	4.00%	7	25.14%	44	175
8	Millet	4.60%	8	15.52%	27	13.22%	23	7.47%	13	8.62%	15	10.34%	18	7.47%	13	32.76%	57	174
9	Yams	4.02%	7	7.47%	13	9.77%	17	6.90%	12	7.47%	13	11.49%	20	12.64%	22	40.23%	70	174
10	Plantains	3.47%	6	7.51%	13	10.98%	19	8.67%	15	5.78%	10	9.25%	16	13.29%	23	41.04%	71	173
11	Vegetables (if yes, please specify)	28.87%	28	25.77%	25	13.40%	13	2.06%	2	1.03%	1	2.06%	2	2.06%	2	24.74%	24	97
12	Fruits (if yes, please specify)	29.59%	29	24.49%	24	15.31%	15	1.02%	1	2.04%	2	1.02%	1	5.10%	5	21.43%	21	98
13	Legumes (if yes, please specify)	17.65%	15	24.71%	21	11.76%	10	0.00%	0	0.00%	0	7.06%	6	4.71%	4	34.12%	29	85

14	Other (if yes, please specify)	13.89%	10	22.22%	16	9.72%	7	2.78%	2	0.00%	0	0.00%	0	0.00%	0	51.39%	37	72

Q52 - What is in your opinion the likelihood of the following crops to benefit significantly from the CRISPR gene editing technology in South America? Rate each on a scale from 1 to 7.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wheat	71.00	78.00	73.26	2.36	5.55	47
2	Maize	71.00	78.00	72.17	1.83	3.33	47
3	Soybean	71.00	78.00	71.72	1.41	1.99	47

4	Rice	71.00	78.00	73.09	2.36	5.57	47
5	Potatoes	71.00	78.00	74.04	2.57	6.62	48
6	Cassava	71.00	78.00	75.13	2.57	6.59	46
7	Sorghum	71.00	78.00	75.28	2.44	5.94	46
8	Millet	71.00	78.00	76.13	2.26	5.11	46
9	Yams	71.00	78.00	75.96	2.23	4.95	46
10	Plantains	71.00	78.00	75.69	2.61	6.79	45
11	Vegetables (if yes, please specify)	71.00	78.00	73.65	2.27	5.17	17
12	Fruits (if yes, please specify)	71.00	78.00	73.61	2.26	5.13	18
13	Legumes (if yes, please specify)	71.00	78.00	73.87	2.50	6.25	15
14	Other (if yes, please specify)	71.00	78.00	74.08	3.33	11.08	12

#	Question	Extremely likely		Moderately likely		Slightly likely		Neither likely nor unlikely		Slightly unlikely		Moderately unlikely		Extremely unlikely		I don´t know		Total
1	Wheat	27.66%	13	23.40%	11	17.02%	8	8.51%	4	2.13%	1	6.38%	3	2.13%	1	12.77%	6	47
2	Maize	51.06%	24	21.28%	10	17.02%	8	2.13%	1	0.00%	0	0.00%	0	4.26%	2	4.26%	2	47
3	Soybean	63.83%	30	19.15%	9	12.77%	6	0.00%	0	0.00%	0	0.00%	0	2.13%	1	2.13%	1	47
4	Rice	36.17%	17	17.02%	8	17.02%	8	6.38%	3	4.26%	2	4.26%	2	4.26%	2	10.64%	5	47
5	Potatoes	14.58%	7	25.00%	12	18.75%	9	4.17%	2	4.17%	2	10.42%	5	0.00%	0	22.92%	11	48
6	Cassava	8.70%	4	10.87%	5	17.39%	8	8.70%	4	6.52%	3	6.52%	3	6.52%	3	34.78%	16	46
7	Sorghum	4.35%	2	8.70%	4	19.57%	9	13.04%	6	10.87%	5	2.17%	1	2.17%	1	39.13%	18	46
8	Millet	2.17%	1	4.35%	2	15.22%	7	6.52%	3	10.87%	5	2.17%	1	6.52%	3	52.17%	24	46
9	Yams	2.17%	1	8.70%	4	8.70%	4	8.70%	4	10.87%	5	6.52%	3	13.04%	6	41.30%	19	46
10	Plantains	11.11%	5	8.89%	4	6.67%	3	4.44%	2	6.67%	3	11.11%	5	6.67%	3	44.44%	20	45
11	Vegetables (if yes, please	11.76%	2	29.41%	5	29.41%	5	0.00%	0	0.00%	0	5.88%	1	17.65%	3	5.88%	1	17

	specify)																	
12	Fruits (if yes, please specify)	11.11%	2	33.33%	6	22.22%	4	5.56%	1	0.00%	0	11.11%	2	5.56%	1	11.11%	2	18
13	Legumes (if yes, please specify)	13.33%	2	33.33%	5	13.33%	2	6.67%	1	0.00%	0	6.67%	1	13.33%	2	13.33%	2	15
14	Other (if yes, please specify)	41.67%	5	16.67%	2	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	41.67%	5	12

Q53 - To what extent do you agree with the following statements on CRISPR gene editing:

Africa

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	4.69	2.24	5.02	169
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.02	1.35	1.82	171
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	3.59	1.92	3.68	171
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.13	1.81	3.29	171
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	4.37	1.63	2.67	169
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	2.97	1.78	3.16	170
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	7.00	3.21	1.51	2.27	170
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	2.64	1.52	2.31	170
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	2.98	1.72	2.96	170
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.03	1.88	3.55	170

Asia

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.12	1.97	3.88	106
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.12	1.34	1.80	105
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.07	1.83	3.33	104
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.46	1.97	3.90	103

5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	4.41	1.79	3.19	105
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.05	1.58	2.50	101
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	7.00	3.10	1.42	2.01	105
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	3.09	1.51	2.27	104
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	3.51	1.74	3.01	102
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.48	1.72	2.97	105

Europe

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.48	1.81	3.27	303
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.03	1.29	1.66	303
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.60	1.75	3.07	301
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.85	1.67	2.79	300
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	5.08	1.60	2.56	301
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.22	1.78	3.16	299
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	6.00	3.09	1.42	2.03	302
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	2.80	1.47	2.15	303
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	3.44	1.67	2.79	303
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.59	1.69	2.87	301

North America

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.14	1.99	3.97	206
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.14	1.31	1.71	207
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.31	1.67	2.80	205
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.71	1.73	2.98	204
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	4.94	1.70	2.88	205
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.23	1.70	2.87	204

7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	7.00	3.27	1.56	2.44	205
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	2.66	1.46	2.15	205
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	3.39	1.62	2.62	205
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.42	1.57	2.48	204

Oceania

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.00	2.18	4.76	21
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	6.00	2.05	1.53	2.33	21
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.43	1.92	3.67	21
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.62	2.26	5.09	21
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	4.57	2.22	4.91	21
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.10	1.79	3.19	20
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	6.00	3.33	1.39	1.94	21
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	3.10	1.80	3.23	21
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	2.00	7.00	3.81	1.76	3.11	21
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.81	1.62	2.63	21

South America

#	Field	Minimum	Maximum	Mea n	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.24	2.06	4.25	62
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.08	1.40	1.95	63
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.06	1.92	3.68	63
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.97	1.69	2.86	63
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	5.00	1.61	2.60	63
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.40	1.77	3.14	62

7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	6.00	3.08	1.49	2.23	63
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	2.78	1.56	2.43	63
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	3.51	1.75	3.08	63
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.60	1.69	2.84	63

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	1.00	7.00	5.11	2.01	4.05	637
2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	1.00	7.00	2.07	1.27	1.61	638
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	1.00	7.00	4.08	1.84	3.38	635
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	1.00	7.00	4.53	1.78	3.17	631
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	1.00	7.00	4.70	1.73	2.99	632
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	1.00	7.00	3.07	1.70	2.88	630
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	1.00	7.00	3.14	1.47	2.17	634
8	The private sector will dominate the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector	1.00	7.00	2.65	1.41	2.00	634
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	1.00	7.00	3.24	1.64	2.70	632
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	1.00	7.00	4.31	1.73	2.99	634

#	Question	Strongly agree		Agree		Somewhat agree		Neither agree nor disagree		Somewhat disagree		Disagree		Strongly disagree		Total
1	CRISPR gene edited foods should be subject to Genetically Modified Organisms regulation.	6.28%	40	10.20%	65	10.68%	68	5.65%	36	8.63%	55	22.92%	146	35.64%	227	637

2	CRISPR gene editing can be one of the major contributors to the solutions of environmental and food insecurity issues	40.13%	256	32.29%	206	18.50%	118	3.29%	21	2.51%	16	1.72%	11	1.57%	10	638
3	CRISPR gene editing technology is currently too expensive to make it a feasible option for developing countries	9.29%	59	15.12%	96	15.28%	97	18.43%	117	11.18%	71	21.57%	137	9.13%	58	635
4	Off-targeted editing is a significant threat for CRISPR gene editing in plant breeding	4.60%	29	11.25%	71	16.80%	106	14.58%	92	13.95%	88	24.41%	154	14.42%	91	631
5	Potential negative side-effects of CRISPR gene editing, have not yet been investigated thoroughly enough to bring gene edited food crops to the market	4.59%	29	8.54%	54	14.72%	93	13.45%	85	16.61%	105	27.53%	174	14.56%	92	632
6	CRISPR gene editing patents will primarily be owned by large plant breeding multinationals	17.78%	112	28.57%	180	19.05%	120	14.92%	94	7.46%	47	7.30%	46	4.92%	31	630
7	In 25 years, the majority of food crops grown globally will be edited using CRISPR gene editing technology	12.78%	81	25.39%	161	23.97%	152	20.50%	130	8.20%	52	8.20%	52	0.95%	6	634
8	The private sector will dominate	21.61%	137	33.44%	212	20.50%	130	13.72%	87	5.21%	33	4.42%	28	1.10%	7	634

	the CRISPR gene editing market in terms of patents and edited crops on the market, rather than the public sector															
9	The CRISPR gene editing market will be dominated by multinationals, startups and scaleups will play a minor role	14.24%	90	25.47%	161	20.89%	132	17.25%	109	8.86%	56	10.28%	65	3.01%	19	632
10	CRISPR gene editing will remain an expensive technology and therefore primarily be applied in developed countries	5.05%	32	11.36%	72	22.56%	143	11.83%	75	16.25%	103	23.50%	149	9.46%	60	634

Appendix C: Statistical tests functions, barriers, crop benefits and beneficiaries CRISPR

Note: For all tests in Appendix C holds, that * corresponds with a significance level <10%, ** corresponds with a significance level <5% and *** corresponds with a significance level <1%

Functions

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Africa	Herbicide resistance	3,68	159	3,89	0,28	0,31	2,46	
	Drought resistance	4,53	168	3,89	0,00	0,00	2,14	***
	Salt soil resistance	2,96	159	3,89	0,00	0,00	2,16	***
	Insect resistance	4,42	161	3,89	0,00	0,01	2,27	***
	Biofortification	4,09	161	3,89	0,31	0,31	2,45	
	Fungus resistance	4,49	166	3,89	0,00	0,00	2,14	***
	Viruses resistance	4,85	164	3,89	0,00	0,00	2,14	***
	Increased shelf life	3,56	158	3,89	0,08	0,10	2,37	*
	Fertilizer use efficiency	3,26	162	3,89	0,00	0,00	2,37	***
	Improved cultivation	3,45	159	3,89	0,03	0,04	2,50	**
	Other	2,61	62	3,89	0,00	0,00	2,79	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Asia	Herbicide resistance	4,28	98	3,95	0,21	0,34	2,58	
	Drought resistance	3,93	100	3,95	0,93	0,93	2,30	
	Salt soil resistance	3,48	95	3,95	0,05	0,14	2,31	
	Insect resistance	4,20	98	3,95	0,26	0,35	2,21	
	Biofortification	3,67	94	3,95	0,31	0,38	2,67	
	Fungus resistance	4,60	98	3,95	0,01	0,03	2,27	**
	Viruses resistance	4,81	100	3,95	0,00	0,00	2,28	***
	Increased shelf life	3,98	95	3,95	0,91	0,93	2,51	
	Fertilizer use efficiency	3,27	94	3,95	0,01	0,03	2,41	**
	Improved cultivation	3,56	94	3,95	0,13	0,24	2,46	
	Other	2,97	37	3,95	0,06	0,14	3,11	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Europe	Herbicide resistance	3,24	291	3,56	0,04	0,04	2,56	**
	Drought resistance	3,82	295	3,56	0,05	0,05	2,24	**
	Salt soil resistance	3,04	291	3,56	0,00	0,00	2,16	***
	Insect resistance	4,01	290	3,56	0,00	0,00	2,32	***
	Biofortification	3,07	290	3,56	0,00	0,00	2,41	***
	Fungus resistance	4,66	297	3,56	0,00	0,00	2,31	***
	Viruses resistance	4,46	294	3,56	0,00	0,00	2,41	***
	Increased shelf life	3,28	291	3,56	0,04	0,05	2,38	**
	Fertilizer use efficiency	3,18	288	3,56	0,00	0,01	2,24	***
	Improved cultivation	3,23	291	3,56	0,02	0,03	2,37	**
	Other	2,28	106	3,56	0,00	0,00	2,71	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
North America	Herbicide resistance	5,02	196	4,00	0,00	0,00	2,44	***
	Drought resistance	3,97	199	4,00	0,84	0,92	2,11	
	Salt soil resistance	3,42	194	4,00	0,00	0,00	2,12	***
	Insect resistance	4,29	196	4,00	0,05	0,07	2,10	*
	Biofortification	3,52	193	4,00	0,01	0,01	2,50	**
	Fungus resistance	4,96	197	4,00	0,00	0,00	2,03	***
	Viruses resistance	4,74	196	4,00	0,00	0,00	2,19	***
	Increased shelf life	4,02	195	4,00	0,94	0,94	2,64	
	Fertilizer use efficiency	3,43	195	4,00	0,00	0,00	2,29	***
	Improved cultivation	3,34	196	4,00	0,00	0,00	2,51	***
	Other	2,30	81	4,00	0,00	0,00	2,96	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Oceania	Herbicide resistance	4,00	18	3,52	0,48	0,48	2,83	
	Drought resistance	4,21	19	3,52	0,16	0,43	2,04	
	Salt soil resistance	2,78	18	3,52	0,20	0,43	2,34	
	Insect resistance	4,17	18	3,52	0,22	0,43	2,18	
	Biofortification	2,83	18	3,52	0,29	0,43	2,64	
	Fungus resistance	4,00	19	3,52	0,37	0,43	2,29	
	Viruses resistance	4,22	18	3,52	0,25	0,43	2,49	
	Increased shelf life	4,22	18	3,52	0,28	0,43	2,67	
	Fertilizer use efficiency	3,00	18	3,52	0,35	0,43	2,28	
	Improved cultivation	2,00	17	3,52	0,01	0,09	2,09	*
	Other	2,43	7	3,52	0,40	0,43	3,15	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
South America	Herbicide resistance	4,53	55	3,88	0,08	0,17	2,67	
	Drought resistance	4,19	57	3,88	0,29	0,45	2,21	
	Salt soil resistance	3,02	54	3,88	0,01	0,07	2,24	*
	Insect resistance	3,93	55	3,88	0,88	0,88	2,33	
	Biofortification	3,34	53	3,88	0,11	0,21	2,44	
	Fungus resistance	4,63	57	3,88	0,02	0,10	2,34	
	Viruses resistance	4,59	54	3,88	0,03	0,12	2,38	
	Increased shelf life	3,78	54	3,88	0,77	0,84	2,51	
	Fertilizer use efficiency	3,25	52	3,88	0,06	0,17	2,40	
	Improved cultivation	3,60	55	3,88	0,39	0,52	2,41	
	Other	3,25	16	3,88	0,43	0,52	3,09	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Public	Herbicide resistance	4,19	540	3,87	0,00	0,01	2,57	***
	Drought resistance	4,13	560	3,87	0,01	0,01	2,19	***
	Salt soil resistance	3,33	537	3,87	0,00	0,00	2,23	***
	Insect resistance	4,21	541	3,87	0,00	0,00	2,26	***
	Biofortification	3,73	535	3,87	0,20	0,20	2,50	
	Fungus resistance	4,71	548	3,87	0,00	0,00	2,21	***
	Viruses resistance	4,62	542	3,87	0,00	0,00	2,27	***
	Increased shelf life	3,67	535	3,87	0,06	0,07	2,52	*
	Fertilizer use efficiency	3,29	536	3,87	0,00	0,00	2,32	***
	Improved cultivation	3,33	536	3,87	0,00	0,00	2,49	***
	Other	2,35	191	3,87	0,00	0,00	2,72	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Private	Herbicide resistance	3,44	214	3,51	0,72	0,79	2,72	
	Drought resistance	3,80	216	3,51	0,06	0,09	2,24	*
	Salt soil resistance	2,63	215	3,51	0,00	0,00	2,01	***
	Insect resistance	4,00	215	3,51	0,00	0,00	2,28	***
	Biofortification	2,62	213	3,51	0,00	0,00	2,33	***
	Fungus resistance	4,58	219	3,51	0,00	0,00	2,18	***
	Viruses resistance	4,61	217	3,51	0,00	0,00	2,33	***
	Increased shelf life	3,55	216	3,51	0,80	0,80	2,42	
	Fertilizer use efficiency	3,01	214	3,51	0,00	0,00	2,30	***
	Improved cultivation	3,31	215	3,51	0,20	0,25	2,33	
	Other	2,38	93	3,51	0,00	0,00	2,97	***

Barriers

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Africa	Policy/legal issues	5,80	169	4,97	0,00	0,00	1,48	***
	Delivery methods	5,00	167	4,97	0,81	0,81	1,63	
	gRNA design	4,59	169	4,97	0,01	0,02	1,98	**
	Intellectual property rights	4,82	167	4,97	0,28	0,31	1,77	
	Consumer perceptions and knowledge gap	5,46	167	4,97	0,00	0,00	1,63	***
	Off-target effects	3,83	167	4,97	0,00	0,00	1,70	***
	Gene drives	3,87	168	4,97	0,00	0,00	1,76	***
	High development costs	5,67	166	4,97	0,00	0,00	1,47	***
	Lack of infrastructure/technical expertise	5,71	170	4,97	0,00	0,00	1,63	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Europe	Policy/legal issues	6,72	307	4,12	0,00	0,00	0,80	***
	Delivery methods	3,88	295	4,12	0,02	0,02	1,71	**
	gRNA design	2,88	296	4,12	0,00	0,00	1,66	***
	Intellectual property rights	4,46	299	4,12	0,00	0,00	1,67	***
	Consumer perceptions and knowledge gap	5,91	301	4,12	0,00	0,00	1,29	***
	Off-target effects	3,43	295	4,12	0,00	0,00	1,67	***
	Gene drives	3,37	299	4,12	0,00	0,00	1,75	***
	High development costs	3,58	298	4,12	0,00	0,00	1,87	***
	Lack of infrastructure/technical expertise	2,75	297	4,12	0,00	0,00	1,68	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Asia	Policy/legal issues	5,45	99	4,24	0,00	0,00	1,66	***
	Delivery methods	3,96	96	4,24	0,15	0,16	1,88	
	gRNA design	3,15	97	4,24	0,00	0,00	1,79	***
	Intellectual property rights	4,80	94	4,24	0,00	0,01	1,74	***
	Consumer perceptions and knowledge gap	4,98	96	4,24	0,00	0,00	1,62	***
	Off-target effects	3,75	96	4,24	0,01	0,02	1,84	**
	Gene drives	3,93	95	4,24	0,08	0,10	1,71	*
	High development costs	4,33	95	4,24	0,64	0,64	1,82	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
North America	Policy/legal issues	4,48	201	3,98	0,00	0,00	1,91	***
	Delivery methods	3,89	197	3,98	0,46	0,46	1,73	
	gRNA design	3,29	197	3,98	0,00	0,00	1,76	***
	Intellectual property rights	4,45	198	3,98	0,00	0,00	1,70	***
	Consumer perceptions and knowledge gap	5,29	198	3,98	0,00	0,00	1,65	***
	Off-target effects	3,37	200	3,98	0,00	0,00	1,57	***
	Gene drives	3,55	199	3,98	0,00	0,00	1,72	***
	High development costs	4,17	198	3,98	0,14	0,16	1,79	
	Lack of infrastructure/technical expertise	3,30	199	3,98	0,00	0,00	1,85	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Oceania	Policy/legal issues	5,22	18	3,98	0,01	0,03	1,73	**
	Delivery methods	4,18	17	3,98	0,72	0,92	2,19	
	gRNA design	2,50	18	3,98	0,00	0,02	1,76	**
	Intellectual property rights	3,94	17	3,98	0,93	0,94	1,92	
	Consumer perceptions and knowledge gap	5,18	17	3,98	0,01	0,03	1,70	**
	Off-target effects	3,33	18	3,98	0,16	0,29	1,88	
	Gene drives	3,94	18	3,98	0,94	0,94	1,83	
	High development costs	4,53	17	3,98	0,27	0,40	1,97	
	Lack of infrastructure/technical expertise	3,11	18	3,98	0,09	0,21	2,08	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
South America	Policy/legal issues	4,49	51	4,10	0,17	0,26	2,01	
	Delivery methods	3,90	49	4,10	0,47	0,53	1,94	
	gRNA design	3,47	51	4,10	0,03	0,06	1,97	*
	Intellectual property rights	4,38	50	4,10	0,27	0,35	1,77	
	Consumer perceptions and knowledge gap	5,04	51	4,10	0,00	0,00	1,64	***
	Off-target effects	3,14	50	4,10	0,00	0,00	1,77	***
	Gene drives	3,52	52	4,10	0,03	0,06	1,91	*
	High development costs	4,78	51	4,10	0,01	0,04	1,90	**
	Lack of infrastructure/technical expertise	4,19	52	4,10	0,75	0,75	2,04	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Public	Policy/legal issues	5,70	561	4,31	0,00	0,00	1,68	***
	Delivery methods	4,30	544	4,31	0,93	0,93	1,76	
	gRNA design	3,45	551	4,31	0,00	0,00	1,92	***
	Intellectual property rights	4,57	546	4,31	0,00	0,00	1,66	***
	Consumer perceptions and knowledge gap	5,51	551	4,31	0,00	0,00	1,52	***
	Off-target effects	3,56	551	4,31	0,00	0,00	1,70	***
	Gene drives	3,62	552	4,31	0,00	0,00	1,72	***
	High development costs	4,28	548	4,31	0,73	0,82	1,94	
	Lack of infrastructure/technical expertise	3,78	555	4,31	0,00	0,00	2,11	***

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
Private	Policy/legal issues	5,65	217	4,09	0,00	0,00	1,88	***
	Delivery methods	3,58	212	4,09	0,00	0,00	1,78	***
	gRNA design	3,15	212	4,09	0,00	0,00	1,81	***
	Intellectual property rights	4,38	214	4,09	0,03	0,03	1,90	**
	Consumer perceptions and knowledge gap	5,40	214	4,09	0,00	0,00	1,64	***
	Off-target effects	3,37	211	4,09	0,00	0,00	1,69	***
	Gene drives	3,46	213	4,09	0,00	0,00	1,85	***
	High development costs	4,36	212	4,09	0,04	0,04	1,91	**
	Lack of infrastructure/technical expertise	3,45	213	4,09	0,00	0,00	2,01	***

Crop benefits

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
Africa	Wheat	4,63	155	4,46	0,39	0,44	2,47	
	Maize	5,98	162	4,46	0,00	0,00	1,87	***
	Soybean	5,13	155	4,46	0,00	0,00	2,31	***
	Rice	4,79	156	4,46	0,10	0,15	2,47	
	Potatoes	4,60	159	4,46	0,44	0,44	2,26	
	Cassava	4,97	159	4,46	0,01	0,02	2,37	**
	Sorghum	4,62	157	4,46	0,41	0,44	2,38	
	Plantains	3,90	157	4,46	0,01	0,02	2,76	**
	Other	3,66	593	4,46	0,00	0,00	2,71	***

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
Asia	Wheat	5,16	86	4,21	0,00	0,00	2,27	***
	Maize	5,51	81	4,21	0,00	0,00	2,24	***
	Soybean	5,60	81	4,21	0,00	0,00	2,13	***
	Rice	6,33	88	4,21	0,00	0,00	1,51	***
	Potatoes	4,94	83	4,21	0,00	0,00	2,26	***
	Cassava	3,29	80	4,21	0,00	0,00	2,60	***
	Sorghum	3,49	81	4,21	0,02	0,02	2,67	**
	Plantains	2,43	79	4,21	0,00	0,00	2,51	***
	Other	3,34	316	4,21	0,00	0,00	2,78	***

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
Europe	Wheat	5,14	277	3,40	0,00	0,00	2,32	***
	Maize	5,13	275	3,40	0,00	0,00	2,38	***
	Soybean	4,50	268	3,40	0,00	0,00	2,50	***
	Rice	3,64	265	3,40	0,15	0,15	2,70	
	Potatoes	5,12	274	3,40	0,00	0,00	2,31	***
	Cassava	1,90	262	3,40	0,00	0,00	2,26	***
	Sorghum	2,48	263	3,40	0,00	0,00	2,44	***
	Plantains	1,71	260	3,40	0,00	0,00	2,21	***
	Other	2,71	1032	3,40	0,00	0,00	2,77	***

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
North America	Wheat	5,15	179	3,98	0,00	0,00	2,18	***
	Maize	6,10	174	3,98	0,00	0,00	1,96	***
	Soybean	6,07	178	3,98	0,00	0,00	1,93	***
	Rice	4,70	176	3,98	0,00	0,00	2,39	***
	Potatoes	4,74	178	3,98	0,00	0,00	2,39	***
	Cassava	2,50	173	3,98	0,00	0,00	2,51	***
	Sorghum	3,63	174	3,98	0,08	0,08	2,58	*
	Plantains	2,09	172	3,98	0,00	0,00	2,30	***
	Other	3,16	698	3,98	0,00	0,00	2,78	***

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
Oceania	Wheat	5,00	16	3,32	0,02	0,06	2,56	*
	Maize	4,31	16	3,32	0,13	0,22	2,50	
	Soybean	4,06	16	3,32	0,25	0,32	2,49	
	Rice	3,94	16	3,32	0,38	0,43	2,74	
	Potatoes	4,94	17	3,32	0,01	0,05	2,36	*
	Cassava	2,29	17	3,32	0,14	0,22	2,76	
	Sorghum	3,76	17	3,32	0,56	0,56	3,09	
	Plantains	1,38	16	3,32	0,01	0,05	2,50	*
	Other	2,57	68	3,32	0,04	0,08	2,90	*

	Variable	Mean	Responses	Weighted average	p.value	p.adjust	std	Significance
South America	Wheat	4,76	46	3,80	0,01	0,01	2,41	**
	Maize	5,87	46	3,80	0,00	0,00	1,85	***
	Soybean	6,26	46	3,80	0,00	0,00	1,44	***
	Rice	4,87	46	3,80	0,00	0,01	2,39	***
	Potatoes	3,94	47	3,80	0,72	0,72	2,62	
	Cassava	2,84	45	3,80	0,02	0,02	2,62	**
	Sorghum	2,69	45	3,80	0,00	0,01	2,48	***
	Plantains	2,32	44	3,80	0,00	0,00	2,67	***
	Other	2,80	149	3,80	0,00	0,00	2,64	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Public	Wheat	4,96	513	3,98	0,00	0,00	2,34	***
	Maize	5,61	508	3,98	0,00	0,00	2,16	***
	Soybean	5,20	505	3,98	0,00	0,00	2,36	***
	Rice	4,71	504	3,98	0,00	0,00	2,47	***
	Potatoes	4,74	508	3,98	0,00	0,00	2,34	***
	Cassava	3,18	498	3,98	0,00	0,00	2,72	***
	Sorghum	3,50	498	3,98	0,00	0,00	2,62	***
	Plantains	2,53	492	3,98	0,00	0,00	2,62	***
	Other	3,24	1877	3,98	0,00	0,00	2,75	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Private	Wheat	5,26	186	3,66	0,00	0,00	2,13	***
	Maize	5,72	189	3,66	0,00	0,00	2,11	***
	Soybean	5,38	183	3,66	0,00	0,00	2,23	***
	Rice	4,05	185	3,66	0,06	0,06	2,76	*
	Potatoes	5,02	191	3,66	0,00	0,00	2,35	***
	Cassava	2,27	183	3,66	0,00	0,00	2,40	***
	Sorghum	2,93	183	3,66	0,00	0,00	2,52	***
	Plantains	1,98	181	3,66	0,00	0,00	2,29	***
	Other	2,76	704	3,66	0,00	0,00	2,77	***

Beneficiaries

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Africa	Food insecurity	3,63	172	3,76	0,29	0,50	1,62	
	Environmental damage Ag	3,59	170	3,76	0,23	0,50	1,80	
	Nutritional value	3,83	169	3,76	0,62	0,62	1,81	
	Producer profits	3,87	167	3,76	0,47	0,62	1,94	
	Yields	4,16	171	3,76	0,01	0,02	1,87	**
	Yield variability	3,83	166	3,76	0,61	0,62	1,81	
	Other	2,19	37	3,76	0,00	0,00	1,54	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Asia	Food insecurity	3,90	92	4,08	0,38	0,89	1,93	
	Environmental damage Ag	4,20	91	4,08	0,59	0,89	2,10	
	Nutritional value	4,05	92	4,08	0,89	0,89	1,83	
	Producer profits	4,30	90	4,08	0,28	0,89	1,91	
	Yields	4,11	96	4,08	0,86	0,89	1,88	
	Yield variability	4,03	87	4,08	0,82	0,89	1,85	
	Other	3,48	23	4,08	0,28	0,89	2,61	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Europe	Food insecurity	3,33	295	3,94	0,00	0,00	1,93	***
	Environmental damage Ag	4,18	294	3,94	0,03	0,06	1,91	*
	Nutritional value	3,91	293	3,94	0,83	0,94	1,99	
	Producer profits	3,95	291	3,94	0,94	0,94	2,00	
	Yields	4,33	293	3,94	0,00	0,00	2,02	***
	Yield variability	4,09	288	3,94	0,22	0,31	2,04	
	Other	2,93	41	3,94	0,00	0,01	2,15	**

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
North America	Food insecurity	3,25	186	3,96	0,00	0,00	1,83	***
	Environmental damage Ag	4,03	189	3,96	0,62	0,62	1,98	
	Nutritional value	4,12	185	3,96	0,24	0,34	1,90	
	Producer profits	4,14	185	3,96	0,20	0,34	1,91	
	Yields	4,39	187	3,96	0,00	0,01	1,97	***
	Yield variability	4,11	183	3,96	0,31	0,37	2,08	
	Other	2,76	46	3,96	0,00	0,00	2,01	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Oceania	Food insecurity	3,53	17	4,06	0,34	0,63	2,21	
	Environmental damage Ag	5,00	17	4,06	0,06	0,44	1,94	
	Nutritional value	3,35	17	4,06	0,19	0,63	2,12	
	Producer profits	4,24	17	4,06	0,73	0,76	2,05	
	Yields	4,47	17	4,06	0,36	0,63	1,81	
	Yield variability	3,88	17	4,06	0,73	0,76	2,06	
	Other	3,60	5	4,06	0,76	0,76	3,13	

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
South America	Food insecurity	3,65	48	4,01	0,20	0,25	1,93	
	Environmental damage Ag	3,75	48	4,01	0,36	0,36	1,93	
	Nutritional value	3,46	48	4,01	0,04	0,23	1,80	
	Producer profits	4,50	48	4,01	0,08	0,23	1,89	
	Yields	4,48	48	4,01	0,13	0,23	2,08	
	Yield variability	4,46	48	4,01	0,13	0,23	2,03	
	Other	3,00	10	4,01	0,22	0,25	2,40	

	Variable	Mean	Repsonses	Weighted Average	p.value	p.adjust	std	Significance
Public	Food insecurity	3,39	540	3,96	0,00	0,00	1,86	***
	Environmental damage Ag	4,03	542	3,96	0,42	0,49	1,95	
	Nutritional value	4,01	538	3,96	0,57	0,57	1,94	
	Producer profits	4,16	535	3,96	0,02	0,04	1,93	**
	Yields	4,33	540	3,96	0,00	0,00	1,94	***
	Yield variability	4,07	526	3,96	0,21	0,30	1,98	
	Other	2,90	106	3,96	0,00	0,00	2,12	***

	Variable	Mean	Repsonses	Weighted average	p.value	p.adjust	std	Significance
Private	Food insecurity	3,52	205	3,82	0,02	0,05	1,85	*
	Environmental damage Ag	3,96	202	3,82	0,30	0,35	1,97	
	Nutritional value	3,62	202	3,82	0,12	0,17	1,82	
	Producer profits	3,79	200	3,82	0,85	0,85	1,91	
	Yields	4,24	207	3,82	0,00	0,01	2,00	***
	Yield variability	4,05	201	3,82	0,10	0,17	2,04	
	Other	2,39	41	3,82	0,00	0,00	1,96	***

Appendix D: IRB approval document

UNIVERSITY OF ARKANSAS

To:	Adriaan Johannes De Lange
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	03/08/2021
Action:	**Exemption Granted**
Action Date:	03/08/2021
Protocol #:	2102314838
Study Title:	CRISPR-Cas9 Drivers & Barriers - A comparative study among US, EU and African plant breeders

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Lawton L Nalley, Investigator

Page 1 of 1