agriculture

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Assessing the Opportunities and Risks of DUS and VCU Variety Testing for Sustainable Production through SWOT Analysis Results

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Citation: Mendler-Drienyovszki, N.; Magyar-Tábori, K.; Mancinelli, R.; Black, L.; Brown, H.; Allam, M.; Udupa, S.M.; Atait, M.; Novarina, E.; Bardelli, T.; et al. Assessing the Opportunities and Risks of DUS and VCU Variety Testing for Sustainable Production through SWOT Analysis Results. *Agriculture* **2024**, *14*, 1817. https://doi.org/10.3390/agriculture14101817

Academic Editor: Daniel Tan

Received: 27 August 2024
Revised: 10 October 2024
Accepted: 11 October 2024
Published: 15 October 2024

Abstract: Within the European Union (EU), new plant varieties to be included in the Common catalog of a member state have to be registered on the national list after plant variety testing processes to establish whether the candidate variety is distinguishable, uniform, and stable (DUS) and meets the cultivation or use value requirement (VCU). Technical development, climate change, and changing consumer needs, including the detection of GMOs, necessitate the innovation of plant variety testing methods. In our study, we assessed new characters, testing methods, and inclusion of additional data for the potential to benefit the DUS and VCU protocols. To achieve our goal, we asked experts to fill in questionnaires for the DUS and VCU methods currently used for a selection of common crops, including potato, maize, lentil, oilseed rape, and perennial grass. Within the EU-funded "InnoVar" project, partners sent out questionnaires to 19 European Countries and to 3 countries outside Europe. Surveys were aimed at analyzing the strengths, weaknesses, opportunities, and threats (SWOT) of the current methods. With their help, it is possible to look for a new direction, opportunity, and strategy to incorporate, together with the innovative new techniques, into the development of the new methods. Our study demonstrated that the SWOT analysis could be used to achieve the set goals. Results obtained after evaluation of surveys confirmed that introduction of new characters such as cold tolerance, nitrogen and water efficiency, etc. has become necessary, as has the inclusion of new test methods (molecular markers, precision techniques, organic farming). The development of high-yielding, disease and/or pest-resistant plant varieties with good adaptability and the accurate evaluation of genotypes play a crucial role in ensuring that farmers can access high-performing plant varieties and contribute to sustainable food production.

Keywords: quality standards; sustainable production; yield performance; SWOT strategies; survey

1. Introduction

The development and availability of high-yielding, disease and/or pest-resistant plant varieties with good adaptability and the accurate evaluation of different genotypes play a crucial role in ensuring that farmers can access high-performing plant varieties and contribute to sustainable food production [1,2]. Within the European Union (EU), crop varieties must be included in a Member State's National List and/or common catalog before being marketed. This requires plant variety testing processes to evaluate whether the variety-candidate is distinct, uniform, and stable (DUS) and meets the requirement of value for cultivation or use (VCU) [3]. National Examination Offices carry out DUS trials according to Community Plant Variety Office (CPVO) protocols, which in turn align to International Union for the Protection of New Varieties of Plants (UPOV) guidelines. Therefore, all CPVO entrusted Examination Offices (EOs) within the EU conduct DUS tests following the principals underlined in the protocols and describing the variety candidates with the same morpho-physiological characters so that the results can be used and compared in each country [3,4].

The DUS test is based mainly on field growing tests, carried out by the authority competent for granting plant breeders' rights or by separate institutions, such as public research institutes, acting on behalf of the authority, such as Research Centre for Plant Protection and Certification (CREA-DC; Italy), and TystofteFoundation (Denmark). The examination generates a description of the variety, using those relevant characteristics (e.g., plant height, leaf shape, time of flowering), by which it can be defined as a variety according to the UPOV Convention (Article 1(vi) of the 1991 Act). The DUS protocol is essential for new varieties to make it to market after being registered on the National Lists of each country. For example, in the UK, this process is managed by the Plant Variety Rights and Seeds Office (PVS), which is part of the Animal and Plant Health Agency (APHA) under the Department for the Environment, Food and Rural Affairs (DEFRA), thereby strengthening the control and harmonization of these accepted international standards.

The other main part of the variety testing process for the inclusion of agricultural plant species in the National Variety List is the test of the variety candidate's cultivation and/or use value (value for cultivation or use: VCU). The VCU protocols are determined at the national level and include rigorous rules that ensure exact evaluation of different traits such as yield, resistance/tolerance to biotic and abiotic stresses, quality traits, and agronomic performance but do not consider some specificities adopted in sustainable farming systems. DUS and VCU tests are used to determine the distinct characteristics and agronomic potentials of newly-developed plant varieties; however, these tests may not provide a comprehensive understanding the market viability or potential risk of varieties as well as agronomic techniques applied in farms addressed to increase the systems sustainability such as in organic farming.

SWOT (strengths, weaknesses, opportunities, and threats) analysis is one of the most widely used strategic planning tools; it provides a comprehensive evaluation of enterprises, structures, specific object, activities, simple or complex processes, etc. by examining its internal strengths and weaknesses as well as external opportunities and threats [5–7]. SWOT analysis collects and efficiently presents information on internal and external factors that affect a business or specific processes. It is as a compilation of internal strengths and weaknesses of organizations derived from an assessment of its resources and capacities, alongside an inventory of external threats and opportunities identified through an analysis of its surrounding environment [8]. Evaluators typically place greater emphasis on external factors instead of internal factors [9]. It is a way of helping to build on what has been done well, to address the gaps, to minimize risks, and to maximize the chances of success. SWOT analysis is not a typical statistical data analysis tool or classical data elaboration, but rather a descriptive analysis of an object. The best solutions and ways can be found to improve and to increase the characters and properties of the studied object. The result of the SWOT analysis is an eight-field SWOT matrix. This matrix not only enables the identification of factors, but also determines their importance and provides a comprehensive overview

of a research problem [10]. The greater the number of actors, such as stakeholders, that participate in the SWOT analysis responses, the more valuable the analysis will be. The results from the analysis can provide answers to build strengths, minimize weaknesses, seize opportunities, and confront threats. Strategy can be characterized as the alignment an organization establishes between its internal resources and capabilities and the opportunities and risks emerging from external factors [11]. In the context of farming systems, SWOT analyses help researchers to manage agricultural products and food security [12]. Other authors [13] performed a SWOT analysis for agricultural and rural development in the Danube region. However, little is known about the application of SWOT analysis in terms of the plant variety testing process.

The alignment phase within the strategy formulation framework includes five methods (SWOT Matrix, SPACE Matrix, BCG Matrix, IE Matrix, Grand Strategy Matrix) that can be applied in any order [14]. These methodologies depend on data obtained from the input stage to align external opportunities and threats with internal strengths and weaknesses. The harmonization of external and internal critical success factors is pivotal for the proficient generation of viable alternative strategies. To achieve integration and coherence between internal abilities and external factors of an organization and specific objects, developing strategies is necessary. This involves aligning sources and skills with external factors [15]. The crucial alignment tool is the SWOT Matrix, which creates four categories of strategies [14]. 'SO' Strategies (Strength-Opportunity) apply internal strengths to use external opportunities, representing an ideal scenario for managers, while 'WO' Strategies (Weakness-Opportunity) specifically target overcoming internal weaknesses by using external opportunities. In the presence of significant weaknesses, efforts are directed towards transforming them into strengths, while confronting major threats prompts organizations to mitigate them and focus on exploiting opportunities. 'ST' Strategies (Strength-Threats) use strengths to either avoid or decrease the influence of external threats. Conversely, 'WT' Strategies (Weakness-Threats) are a defensive method aimed at mitigating internal weaknesses and preventing external threats [14]. With the help of SWOT analysis in variety testing programs, we can obtain not only comprehensive results about the advantages and disadvantages of the present variety testing processes (DUS and VCU), but also enable researchers and breeders to uncover valuable insights regarding market positioning, potential challenges during cultivation or commercialization stages, as well as opportunities for further improvement such as the values for the increasing of the sustainability of farming systems. After specifying the object of SWOT analysis, the experts on the object of study list the strengths and weaknesses as well as opportunities and threats. Various tools exist to guide experts on the subject through the process, often using a series of questions under each of the four elements.

The 'InnoVar' project (project funded under the EC call Research and Innovation action, SFS-29-2018; https://www.h2020innovar.eu) improves next generation plant variety testing by developing tools and models that augment current practices with specific objectives, such as exploring the potential for phenomics and DUS characters to be used as VCU characters or vice versa and to determine the performance of varieties under different 'growing scenarios' and agronomic management techniques. To achieve all the objectives of the project, partners with significant expertise in various relevant fields were involved, working in cooperation throughout Europe and beyond. The project conducted a Europe-wide trial series focusing on wheat, utilizing a range of management regimes, including drought, reduced input, and organic growing scenarios. Therefore, the InnoVar project partners are a great resource to be exploited to better understand specific values and needs through a SWOT analysis. Some aspects and characteristics that need to be clarified and understood are:

- for DUS: the protocol conformity to an internationally established standard, whether the character complete lists can be considered strength, the correctness of inaccurate expression categories (e.g., determination of seed color, and other factors), the lack of total objectivity for non-measurable characters, the use of molecular markers, etc.;

- for VCU: quality control, testing in organic management, the lack of international standardization on methodologies, the lack of available data in open access sources, the cost of post-registration tests, the costs for tests in organic management and for molecular studies supported by governments, etc.

We consider one of the above-mentioned aspects, organic management, because the EU aims to significantly increase the area under organic production within the next 10 years [16]. This is shown by the recent Commission Implementing Directive (EU) 2022/1647 (23 September 2022), amending Directive 2003/90/EC, as regards a derogation for organic varieties of agricultural plant species suitable for organic production, which gives breeders the possibility to register organic varieties in the Community Catalogue.

Currently, VCU testing is generally conducted under conventional management practices only. This relies heavily on synthetic inputs such as fungicides and herbicides. Thus, many important features of organic and sustainable farming are not evaluated in traditional VCU experiments. In many cases, there is no information about the cultivars' ability to be cultivated under organic and sustainable conditions.

The main aim of our study was to reveal and define the specific requirements that arise during VCU and DUS variety testing processes. This will contribute to decision-making when seeking to update the plant variety testing process.

The overall objectives of this study were to evaluate the current methods in DUS and VCU variety trials in different EU member states and to obtain a comprehensive review of the strength, weakness, opportunities, and threats detected in the DUS and VCU protocols by SWOT analysis.

2. Materials and Methods

2.1. Background of the Study

The adopted approach to reach the aim of this study was through a fixed process of research methodology structure defined at the outset of the work (Figure 1). First, specific questionnaires relative to the testing of VCU and DUS protocols for various crops were arranged in advance. The questionnaires were circulated among the InnoVar project partners (Table 1). Then, questionnaires were circulated to experts (examination offices, research institutes, universities) within and outside Europe who were asked to respond for the SWOT analyses. This also included partners in the InnoVar project and partners in the INVITE project, which was funded under the same EC call (Research and Innovation action; SFS-29-2018). In each country, there are not many people with deep expertise concerning the testing of VCU and the DUS protocol who are officially accredited and scientifically recognized, so the highest experts were contacted in 19 European countries and in 3 countries outside Europe.

Table 1. Partners of the InnoVar project.

Institutions	Acronym	Country
Agri-Food and Biosciences Institute	AFBI	UK
University College Dublin	UCD	Ireland
Consejo Superior de Investigaciones Científicas	CSIC	Spain
RSK ADAS Limited	ADAS	UK
Debreceni Egyetem	UNIDEB	Hungary
Università degli studi della Tuscia	UNITUS	Italy
TystofteFoundation	TYST	Denmark
I.P. Pragmatics	IPPL	UK
International Centre for Agricultural Research in the Dry Areas	ICARDIA	Lebanon
Alma Mater Studiorum Università di Bologna	UNIBO	Italy

Table 1. *Cont.*

Institutions	Acronym	Country
Department of Agriculture, Food and the Marine	DAFM	Ireland
Department for Environment, Food and Rural Affairs	DEFRA	UK
Agriculture and Horticulture Development Board	AHDB	UK
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria	CREA-DC	Italy
Origin Enterprises PLC	ORIGIN	Ireland
Universidad Politécnica de Madrid	UPM	Spain
International Soil Reference and Information Centre	ISRIC	The Netherlands
HORTA S.r.l.	HORTA	Italy
CONSULAI, Consultoria Agroindustrial LDA	CONSULAI	Portugal
National University of Ireland Maynooth	NUIM	Ireland
Lesprojekt-Služby Ltd.	LESP	Czech Republic

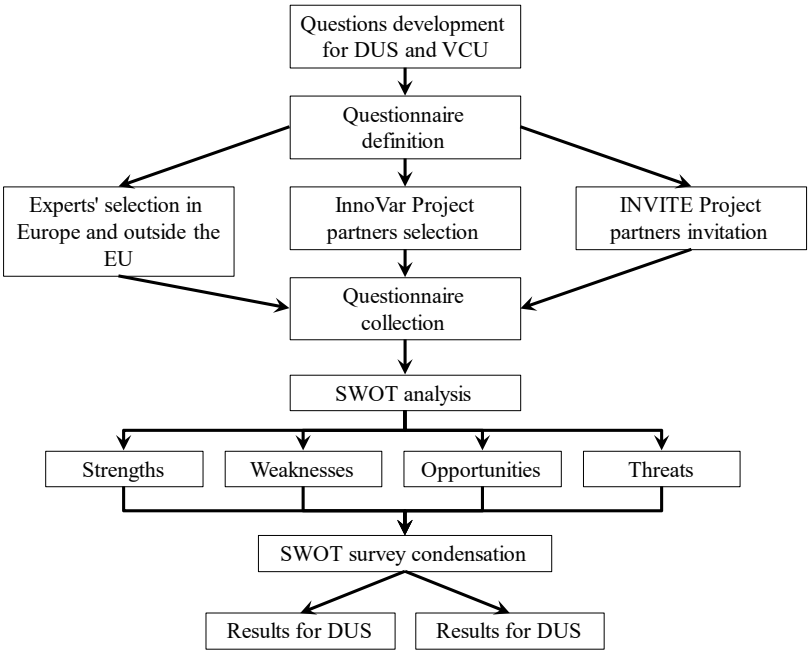

Figure 1. Research methodology structure.

2.2. Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis

A SWOT analysis generally requires one to first specify the intended objective for a group or single object. From there, the experts on the object of study list the strengths and weaknesses as well as opportunities and threats. Various tools exist to guide experts on the subject through the process, often using a series of questions under each of the four elements. In our study, a questionnaire was circulated and then SWOT matrices were created for each crop sub-set containing the answers from respondents in text form. This is because the analysis objective is to identify thoughts and opinions across Europe with the focus on the improving of quality and efficiency of DUS and VCU testing.

2.3. Questionnaires Compilation

The idea came from the InnoVar project, translating the wheat DUS and VCU methodology to other plant species, including oilseed, legume, brassica, tuber crop, and grass. A representative species of each crop sub-set was selected for detailed analysis (Table 2), with the intention being to cover species with different reproductive systems and part-

ner DUS/VCU expertise and resources. This process benefitted from the possibility of collaborating with INVITE project partners.

Table 2. Selected crop sub-set and species.

Crop Sub-Set	Plant Species
Oilseed (and Brassica)	Oilseed rape (*Brassica napus* L.)
Legume	Lentil (*Lens culinaris* L.)
Maize	Maize (*Zea mays* L.)
Tuber crop	Potato (*Solanum tuberosum* L.)
Grass	Perennial ryegrass (*Lolium perenne* L.)

The questionnaires contained basic questions about the strengths, weaknesses, opportunities, and threats of DUS (Table 3) and VCU testing (Table 4). Previously, as part of of the InnoVar project, DUS and VCU protocols from several European countries were collected, reviewed and discussed with experts such as EOs, breeders, and other relevant researchers. The questionnaires were based on the results of these discussions and were plant species-specific.

Aiming to better understand the reality of VCU and DUS testing in Europe and beyond, it was decided to involve a larger number of experts by sending them the questionnaire. Finally, we received the filled-out surveys from each contacted country. We received completed questionnaires from the following 14 European countries: Italy, Estonia, Denmark, Austria, Slovakia, the Netherlands, Poland, Hungary, United Kingdom, Ireland, France, Belarus, Sweden, and Finland. Additionally, 3 non-European experts sent back the filled questionnaire from Morocco, Uruguay, and South Africa. Four partners of the InnoVar project also contributed to the completion of questionnaires: Agri-Food and Biosciences Institute (AFBI); Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA); University of Debrecen (UNIDEB); and the International Center for Agricultural Research in the Dry Areas (ICARDA). All answers were evaluated.

Table 3. Questionnaire for specific aspects of DUS.

	SWOT—DUS
S	-Do you consider the DUS protocol used conforms to an internationally accepted standard: Please, explain your answer: -Scale used for expression level: Do you think it is a Strength? Please, explain your answer: -The groups of characteristicss: Do you think the characteristics lists complete and so can be considered Strength? Please, explain your answer: -The characteristicss used for differentiating varieties: Do you think it can be considered Strength? Please explain your answer: -Do you have any other aspects/characteristicss which can be considered? If yes, please add:
W	-Inaccurate expression categories (e.g., determination of seed colour): Do you think is it correct? Please explain your answer: -Lack of total objectivity for non-measurable characteristics (visually registered, pseudo-qualitative traits, such as shape, etc): Do you think is it correct? Please explain your answer: -Do you have any other aspects/characteristicss which can be considered? If yes, please add
O	-Use of molecular markers: Does molecular marker testing to be considered an Opportunity (O) and it should be supported by the government? Please explain your answer: Is this also a Threat? -Do you have any other aspects or innovations regarding molecular markers which can be considered? If yes, please add
T	-Please suggest here any other aspects or innovations which can be considered

The scale level of the data depends on the type of characteristic expression and the method used to capture that representation [17]. The type of scale may be nominal, ordinal, interval, or ratio. When evaluating measured or counted characteristics, DUS assessment relies on the observed values, which are converted into state of expression solely for distinctness analysis and describing varieties [18].

Table 4. Questionnaire for specific aspects of VCU.

	SWOT—VCU
S	Quality control: Do you consider quality control a Strength in your scientific knowledge? Please explain your answer: Is quality control also a Weakness, Opportunity or Threat? Varieties are tested in organic conditions: Are varieties tested in organic management? Do you think add organic test could be a Strength? Is this also a Weakness, Opportunity or Threat? Do you have any other aspects or innovations which can be considered? If yes, please add
W	-Lack of international standardization on methodologies (e.g.,: minimum values for content of protein, sugar, fat, etc.): Do you think this is a Weakness? Please explain you answer: -Lack of international standardization in the protocols: Do you think this is a Weakness? Please explain you answer: -Lack of available data: Do you think this is fundamental? -Varieties are tested only in conventional management: Do you think this is a Weakness? Please explain you answer: Is this also a Strength, Opportunity or Threat? -Number of organic trial locations are low: Is it correct in your Country? -Lack of national and international priority of characteristics during the VCU test: Do you think this is a Weakness? Do you have any other aspects or innovations which can be considered? If yes, please add:
O	-Involvement of special traits (e.g., weed competitiveness, nitrogen use efficiency, etc.): Do you think is this an Opportunity? Please explain your answer: -Decrease cost of post-registration tests: Do you think is this an Opportunity if applied? If it is not applied, do you think is Weakness or Threat? -Do you have any other aspects which can be considered? If yes, please add:
T	-Organic trials are more expensive than the conventional ones: Is it correct in your Country? If yes, do you think it should be supported by the government because it could become an Opportunity? -Expensive molecular studies: Does molecular testing have a reason to be applied? If yes, do you think it should be supported by the government because it could become an Opportunity? Do you have any other aspects or innovations which can be considered? If yes, please add:

Groups of characteristics can be precisely defined, are derived from one genotype or genotype combination, and consistent records can be repeated, thereby making the DUS characteristics quite robust. They also provide sufficient diversity in the species to be effective in the identification of variety (i.e., Distinctness) (Figure 2).

Figure 2. The ear characteristics of durum wheat are important variety traits (Source 'InnoVar' experiment, Nyíregyháza, Hungary).

2.4. Data Analyses

The answers to the questionnaires contain the opinions of specialists. All text responses were analyzed for each plant species, from which we can obtain an insight into the strengths, the shortcomings of the currently used DUS and VCU methods, and their potential for innovation. The answers—which are not in text form and are instead presented graphically–were quantified and divided into five categories, (1)—Yes; (2)—Yes, conditionally; (3)—Yes, partly; (4)—No; (5)—Not relevant, where 'Yes' means that the respondent agrees with the statement or considers it correct. In our case, where there was no answer supplied, we mark it as 'Not relevant'. Frequencies of the values were evaluated with SPSS software, version 22.0 (SPSS®) for Windows. The frequency of VCU analysis of the lentil has been exluded, since the lentil is a horticultural plant and the variety testing procedures do not include VCU experiments; these answers remain theoretical for now.

3. Results

3.1. Results of SWOT Analysis for DUS Protocols

This strategic approach provides a deep understanding of the current state of the DUS variety testing and allows for a detailed description of advancements and challenges. Consequently, it offers valuable insights into the possibilities for future developments and the internal or external influences affecting the system.

In Tables 5–9, the summary of SWOT analysis results for each plant species are reported.

Table 5. Strengths, weaknesses, opportunities, and threats of DUS protocol of maize.

Strengths	Weaknesses
-Conforms to all international accepted standards; -Scale used for expression level of characteristics (mostly) covers all possible states; -Complete characteristics list; -The characteristics are enough to assess distinctness between varieties.	-Lack of precise expression level of some characteristics; -Lack of total objectivity for non-measurable characteristics.
Opportunities	**Threats**
-Molecular marker testing; -Accessible database of the variety description.	-No threats identified

Table 6. Strengths, weaknesses, opportunities, and threats of DUS protocol of lentil.

Strengths	Weaknesses
-Conforms to all international standards; -Characteristics are sufficient for describe and distinguish new varieties.	-Some characteristics are difficult to be objectively assessed; -Scale used for expression level not sufficient; -List of characteristics is not complete.
Opportunities	**Threats**
-Molecular marker testing.	-No threats identified.

Table 7. Strengths, weaknesses, opportunities, and threats of DUS protocol of perennial ryegrass.

Strengths	Weaknesses
-Conforms to all international accepted standards; -Scale used for expression level of characteristics covers all possible states; -Complete characteristics list; -Characteristics are sufficient to describe and distinguish new varieties.	-Some characteristics are difficult to be objectively assessed.

Table 7. *Cont.*

Opportunities	Threats
-Authentication of seed test could be carried out by molecular markers; -Use of SNPs or other genetic markers; -Create database which can monitor genetic diversity and drift of a species.	-Incorrect use of molecular markers and misinterpretation of results, and/or unregulated use; -disregard of potential effect of culture in multispecies/multivariety swards.

Table 8. Strengths, weaknesses, opportunities, and threats of DUS protocol of potato.

Strengths	Weaknesses
-Conforms to all international accepted standards; -Scale used for expression level of characteristics (mainly) covers all possible states; -Complete characteristics list; -Characteristics are sufficient to describe and distinguish new varieties.	-Some characteristics are difficult to be objectively assessed; -Scale used for expression level not objective enough.
Opportunities	**Threats**
-Molecular marker testing.	-No threats identified.

Table 9. Strengths, weaknesses, opportunities, and threats of DUS protocol of oilseed rape.

Strengths	Weaknesses
-Conforms to all international accepted standards; -Scale used for expression level of characteristics covers all possible states; -Complete characteristics list; -Characteristics are sufficient to describe and distinguish new varieties.	-Some characteristics are difficult to assess objectively.
Opportunities	**Threats**
-Molecular marker testing; -Introducing of new techniques.	-GMO

3.1.1. Maize (*Zea mays* L.) DUS

Strengths:

All European countries adopted the National Guidelines for DUS testing of maize, which are prepared based on UPOV Test Guidelines—TG/2/7 and CPVO Technical Protocol- TP/002/3 Date: 11 March 2010. National Guidelines for DUS testing of maize conform to an internationally accepted standard and fulfil current requirements represented by international UPOV and community CPVO office. Although it is unanimously agreed that the scale used for expression level is defined properly, for some characteristics it is difficult to assign the proper expression level, particularly in the middle range values. The list of characteristics used for DUS testing of maize is complete and this is considered as a Strength because characteristics are subject to international harmonization and updating. Moreover, characteristics are regularly discussed at working group meetings organized by UPOV and CPVO to ensure their suitability for distinctness and descriptions of new varieties. The characteristics used for differentiating varieties have been found to be useful grouping characteristics. Grouping characteristics can be used to organize the growing trial so that similar varieties are excluded from the trial, which has been agreed internationally. The representative from Slovakia suggested that in the near future, extension of the current number of characteristics will be needed to include new characteristics for better distinctness among maize varieties.

Weaknesses:

In the case of presence of inaccurate expression categories, such as determination in the ear of coloration of silks, it is true that some characteristics are very difficult to identify and assign the correct score level, but the experience of the crop expert and the use of the reference varieties can help to determine the correct note, or preparation of more precise expressions, could be a solution. Despite the instructions given in the CPVO protocol and the list of reference varieties, the lack of total objectivity for non-measurable characteristics (visually registered, pseudo-qualitative traits, such as shape) is potentially problematic. According to the respondents, new tools that help in the description of variety candidates or provide deeper explanations with illustrations or photos could help to avoid this issue.

Opportunities:

EO's are largely in agreement on the introduction of molecular markers to improve the management of the reference collection and the distinctness test, but the respondents added that the high costs should be supported by the government. Multiple respondents shared an opinion on data sharing of DUS data between European countries. Currently, the main issue is the different environmental, climatic, and soil conditions. Despite this. data exchange between DUS tests is a step that would improve the management of the reference collection and the DUS test. In Europe, two groups of three countries each are currently sharing DUS data for maize.

3.1.2. Lentil (*Lens culinaris* Medik.) DUS

Strengths:

The internationally accepted and used guidelines for DUS test of lentil is CPVO/TP-210 (Figure 3). The characteristics scale used for expression level is appropriate, but in some cases, it is slightly subjective. For some characteristics, the scale or aspects are not enough (e.g., determination of plant habitat or seed color). The group of characteristics list was complete, but due to the appearance of a winter type of lentil, it is necessary to consider the introduction of new characteristics into the variety testing processes. There is an increasing demand for the breeding of overwintering legumes, so it is necessary to check and supplement the list of properties of the UPOV descriptions. The characteristics used for differentiating varieties are considered as Strengths.

Figure 3. Uniform and heterogenous seed colors of different lentil breeding lines (Source: photos were taken by Nóra Mendler-Drienyovszki).

Weaknesses:

There are only four choices on the list in the case of the determination of main seed color. In reality, lines/cultivars express colors that are not included in the scale, so the expression of characteristic categories is considered as a Weakness. In addition, the list of characteristics is not complete enough to enable variety description, and, in some cases, it is difficult to assess some characteristics. The use of example varieties helps assessment work.

Opportunities:

All respondents agreed that the introduction of molecular markers in the variety testing process is a necessity. They also agreed that this would increase the costs, so the governments should support these examinations.

3.1.3. Perennial Ryegrass (PRG) (*Lolium perenne* L.) DUS

Strengths:

National Guidelines for DUS testing of perennial ryegrass were prepared based on UPOV Test Guidelines—TG/4/8 and CPVO Technical Protocol—TP/004/1. National Guidelines for DUS testing of perennial ryegrass conform to an internationally accepted standard, represented by UPOV and CPVO (Figure 4).

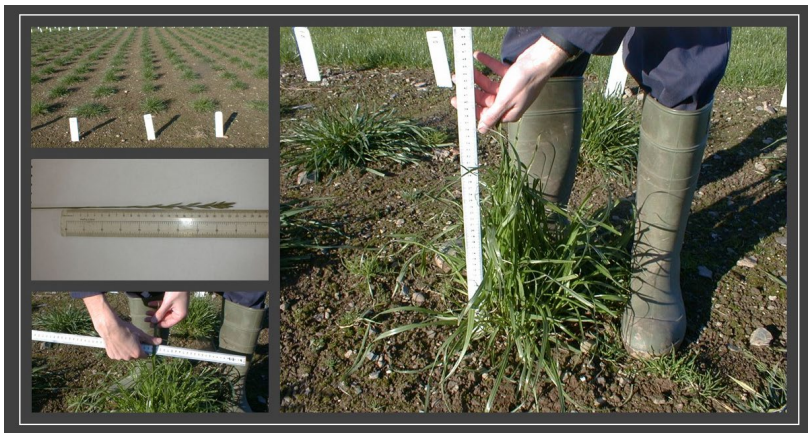

Figure 4. DUS observations of perennial ryegrass (source: photos were taken by Lisa Black).

The scale used for the expression level of characteristics covers all possible states of expression characteristics and is one of the most logic scales to use (1–9).

Groups of characteristics can be precisely defined, are derived from one genotype or genotype combination, and consistent records can be repeated, making the DUS characteristics quite robust.

Characteristics that are used for differentiating varieties have been agreed as useful grouping characteristics. Grouping characteristics are used to organize the growing trial so that similar varieties are grouped together. According to the answer by the EO from the Netherlands—which is considered both a Strength and Weakness—it is challenging to determine the distinctness of varieties with a limited set of characteristics, especially considering the very large reference collection. The characteristics cover the morphological variety identification, but the genetic background of perennial ryegrass and the year interaction caused by the environmental conditions makes it a Weakness.

Weaknesses:

Specific expressions are not measured in herbage DUS; as such, inaccurate expression categories can be considered a Weakness. When there are potential candidates that do not meet the distinctness criteria after two full tests, they are usually sown alongside the reference varieties/variety it could not be distinguished from for another 2-year visual assessment comparison (i.e., no DUS testing conducted on these plots). This can assist the breeder in accepting the lack of distinctness in the DUS test. Equally, they can advise on what special tests might measure any visual difference that have been noted in the field but not expressed or assessed in the spaced plant tests.

According to the respondents, it is not appropriate to talk about lack of "total" objectivity. Of the 22 characteristics scored in the herbage DUS test, only 6 are visually scored (or (pseudo) qualitative). These are scored by highly trained and skilled crop experts, with many years of experience, following the UPOV convention. Although it is not as objective as quantifiable characteristics, it still follows a defined procedure for measuring, estimating, and differentiating visual characteristics by experienced personnel. In the Netherlands and

the UK, there are always two testers responsible for a crop, and before visual observation experts starts, they calibrate themselves based on example varieties.

Opportunities:

Use of molecular markers was identified as a key opportunity, with three major scientific advantages identified. First, it will enable us to better understand expression of phenotypes between the genetic x environmental interaction; second, it will enable us to distinguish and define new varieties from one another; and third, it will enable us to trace the origins of specific/interesting traits and allow better control over how these are or are not selected for in subsequent generations and/or genetically modified organisms.

Perennial ryegrass varieties are groups of individual genotypes with similar phenotypes. Use of SNPs or other genetic markers to group genotypes and identify a variety is a useful tool in safeguarding plant breeders' rights. This method could also allow for the production of a database that can be used to monitor the genetic diversity and drift of a species.

Introducing new techniques like RGB/depth camera would be also an Opportunity.

Threats:

Use of molecular markers could be a potential threat if it is not understood, regulated, and governed correctly, which is why governments should be an integral part of, and constantly involved in, any new research or technology in this area. This will prevent the creation of a knowledge gap or development of fear of the innovations themselves.

Another aspect that might be considered important is the fact that more and more farmers are selecting to grow grasses with other species for environmental reasons (e.g., with clover to reduce external nitrogen input), known as multispecies swards. Special tests could be developed for these types of systems. Although more aligned to the VCU rather than DUS, it may be interesting to catalogue this at the molecular level to see what happens to potential genetic expression when varieties are grown in multispecies/multivariety swards.

3.1.4. Potato (*Solanum tuberosum* L.) DUS

Strengths:

National Guidelines for DUS testing of potato conform to an internationally accepted standard, represented by UPOV and CPVO (UPOV Test Guidelines—TG/23/6 and CPVO Technical Protocol—TP/023/3).

The potato is a difficult species to examine for DUS. Many characteristics are tested on a visual basis only, without the possibility of measurement. Not all the respondents agree that the scales used for expression level would be a Strength. Experts from Italy and Poland answered that this scale allows description of a characteristic in an effective way. According to other respondents, this is not a Strength because sometimes it is not sufficiently objective. For example: the length of axillary shoots on young light-sprout (Figure 5): short: 3; medium: 5; long: 7; and the scale of some characteristics is marked from 1 to 5, while some others from 1 to 9. It is recommended to standardize the scale from 1 to 9 (for example: characteristic 24—Inflorescence: size being 3 to 5 must be changed to 1 to 9). The Slovakian EO regularly makes revisions of expression level following requests to their UPOV and CPVO working groups.

List of traits in the table of characteristics of National Guidelines for DUS testing of potato are complete (total 37 characteristics), sufficient for assessment of variety distinctness, and are subject to international harmonization, updating, and discussion at working group meetings organized by UPOV and CPVO. New features can always be added later when the protocol is revised in consultation with other EO's and the CPVO.

The morphological characteristics of potato cultivars are very specific and can be very different. Characteristics that are used for differentiating varieties have been agreed as useful grouping characteristics, which are used to organize the growing trial so that similar varieties are grouped together.

Figure 5. Different light-sprouts of potato breeding lines (Source: photos were taken by Katalin Magyar-Tábori).

Weaknesses:

Experts believe that the expression categories of traits are inaccurate as some characteristics are very difficult to objectively assess. This has been discussed many times by those EOs entrusted with potato DUS testing, who agree that the lack of objectivity is problematic. Accurate expression of characteristics requires the up-skilling of crop experts, better exchange of information and experiences between EOs, better explanation in guidelines, and the use of helpful illustrations and photographs.

The lack of total objectivity for non-measurable characteristics is a Weakness and can potentially be solved by the crop expert's experience and by using reference varieties expressing different classes. Furthermore, it could be resolved by using image analysis techniques. According to the experts from the Netherlands, it is not a Weakness, because in addition to the potato protocol, a calibration book can also be used in which photos are taken of every characteristic, such as the tuber shape and light-sprout shape.

Even though the potato genome is complex (strongly heterozygous and autotetraploid), testing the genotype instead of the phenotype can be conducted, since the propagation is performed vegetatively according to the Hungarian expert.

Opportunities:

Molecular marker testing should be considered an opportunity and should be of help in case of doubts about the identity and distinctness of the variety. The molecular marker information in the EU Potato Database provides an efficient DNA profiling tool to identify those varieties that should be added to the national collection. Varieties that are not in the reference collection but have high genetic similarity to the given candidate variety should be added to its DUS growing trial. This will decrease the risk of missing similar varieties.

The Plant Breeding and Acclimatization Institute in Poland carries out tests of virus resistance in potato varieties for the Research Centre for Cultivar Testing (COBORU). COBORU has signed an agreement on participation in the European Potato Database. Examination Offices have sent coded samples of candidate potato varieties to the laboratory in Naktuinbouw, the Netherlands, to check whether a new potato variety candidate matches with an existing variety and to minimize the number of lines in the field from the reference collection. The morphological description will always exist and will not be replaced by only a DNA profile.

3.1.5. Oilseed Rape (*Brassica napus* L.) DUS

Strengths:

National Guidelines for DUS testing of oilseed rape conform to an internationally accepted standard, represented by UPOV and CPVO (UPOV Test Guidelines—TG/036/6 and CPVO Technical Protocol—TP/036/3).

The scale used for expression level allows the description of a characteristic in an effective way; the list of characteristics is complete, and these characteristics are sufficient to describe and distinguish new varieties. In oilseed rape, the expression categories are accurate and are based on international cooperation during CPVO and UPOV working groups. The currently used non-measurable characteristics are observed with an objective approach.

Weaknesses:

There is only one aspect that can be considered as a weakness. A common methodology should be developed for determining measured characteristics and conducting their analysis. The number of observations of measurable characteristics requires a lot of work and time at the appropriate growth stages and are specific for each measured characteristic. The representative from Belarus highlighted that the lack of objectivity for non-measurable characteristics can be problematic because, during DUS testing, the expert may inaccurately determine expression categories through of lack of experience or because of incorrect conditions for determination of expression categories (e.g., bright day light for determination of seed color). According to an expert in South Africa, however, although total objectivity will not work for these characteristics, the fact that it is less time consuming than measured characteristics, and that good illustrations and explanations exist, make this a Strength rather than a Weakness.

Opportunities:

The use of molecular markers is an opportunity to reduce the number of similar varieties identified during the DUS testing; to check the formula in the hybrid varieties; and to determine more characteristics to quickly check whether a lot of seed is or not of that variety (e.g., in seed certification). All respondents agreed that the of use of molecular markers in DUS testing is a strength, but, according to one of the respondents, it is also a threat. The complex nature of the DUS test for oilseed rape means it can be very difficult to establish the correct link between a molecular marker and a morphological characteristic. Moreover, the use of molecular markers may lead to lack of one unified approach to DUS testing in all UPOV member countries. The introduction of new techniques like image analysis with artificial intelligence with scanners (Zoom agri, for example) or drones would also be an Opportunity to assess some morphological characteristics such as shape, green color intensity, color of seeds, etc. to distinguish varieties.

Threats:

According to non-European respondents, lack of knowledge transfer can be a Threat, and continuing education of DUS experts is important. Sharing knowledge through exchange visits to plots and laboratories would prove invaluable when seeking to develop visual expertise, critical in this crop.

It was also highlighted that genetically modified organism (GMO) innovations—specific to this *Brassica* genus—can be considered as a Threat and should be tested thoroughly to ensure that local natural environments and species genetic pools are not irreversibly contaminated.

Distribution of answer frequencies concerning the most important questions are reported in Figure 6.

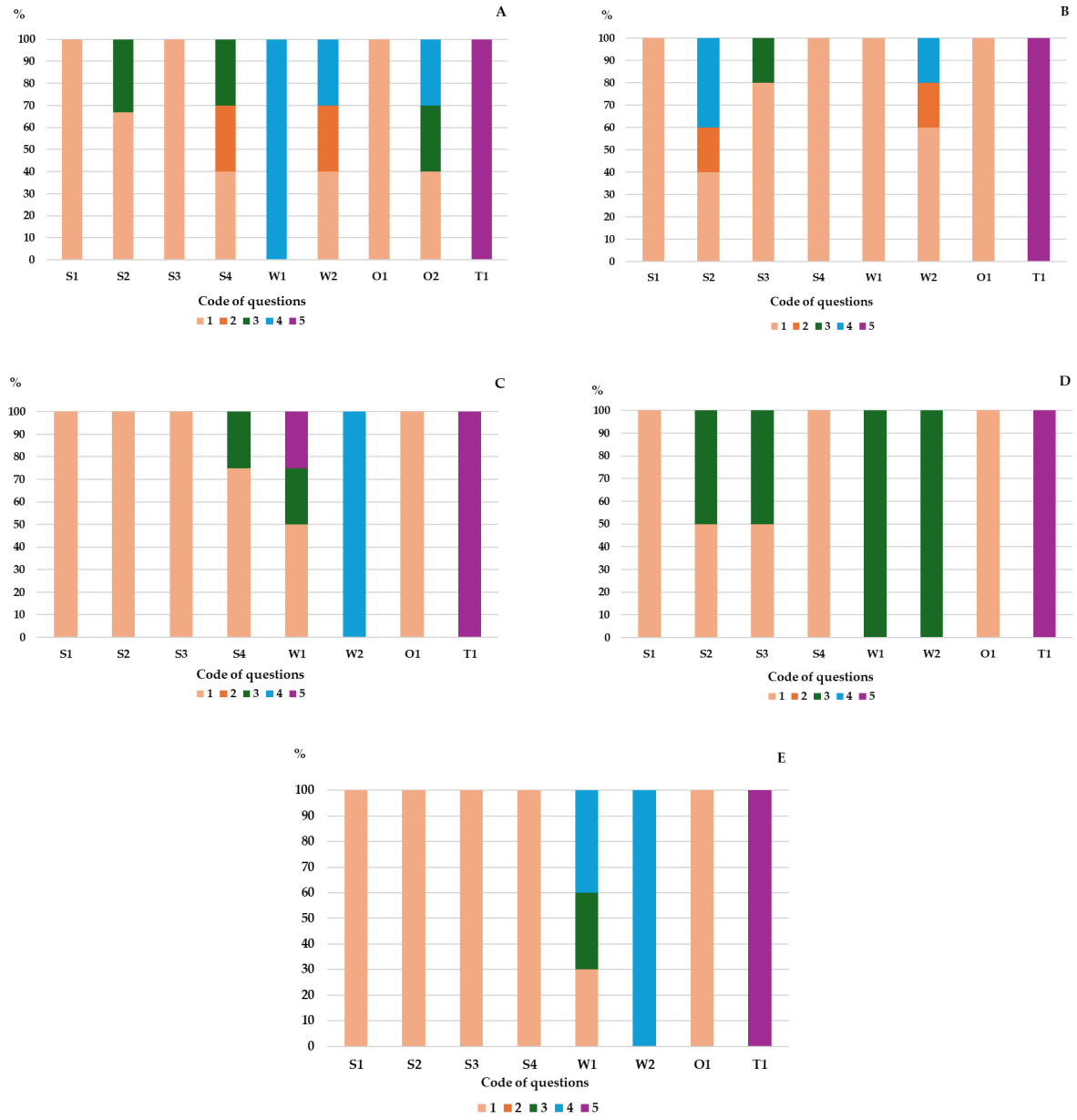

Figure 6. Frequency figures of answers to the SWOT questionnaire regarding DUS tests of maize (**A**), potato (**B**), perennial ryegrass (**C**), lentil (**D**), and oilseed rape (**E**), where S, W, O, and T mean strengths, weaknesses, opportunities, and threats, respectively. Codes of questions: S1. Do you consider the DUS protocol used conforms to an internationally accepted standard? S2. Scale used for expression level: Do you think it is a Strength? S3. The groups of characteristics: Do you think the characteristic lists complete and so can be considered Strength? S4. The characteristics used for differentiating varieties: Do you think it can be considered Strength? W1. Inaccurate expression categories (e.g., determination of seed color): Do you think it is correct? W2. Lack of total objectivity for not measurable characteristics (visually registered, pseudo-qualitative traits, such as shape, etc.): Do you think it is correct? O1. Use of molecular markers: Does molecular marker testing to be considered an Opportunity? O2. (in the case of maize) Priority of DUS data sharing between European countries. T1. Please suggest here any other aspects or innovations which can be considered! Categories: (1)—Yes; (2)—Yes, conditionally; (3)—Yes, partly; (4)—No; (5)—Not relevant.

3.2. Results of SWOT Analysis for VCU Protocols

One relevant aspect concerning VCU variety testing is related to sustainable farming management and specifically to organic certified materials. Organic certified food and

farming have been growing year by year around the world and continues to increase. In Europe, the total organic farmland area grew to 10.4% in 2022 [19]. Sustainable food systems are an important focus and objective of the European Green Deal. Under the Farm to Fork strategy, the European Commission has set a target of at least 25% of the EU agricultural land being under organic farming by 2030. The new organic regulation (EU) 2018/848 on "Organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007" has the objective of safeguarding a high level of agricultural diversity, which could be achieved by using i.e., varieties selected for organic and sustainable agriculture. Nevertheless, the lack of national and international priority on characteristics during VCU testing is still not considered a weakness of the system for all the countries. This is perhaps because the international priority is given by the directive 2003/90/EC, in which are indicated the characteristics used during the examination of the value for cultivation or use (1. Yield, 2. Resistance to harmful organisms, 3. Behavior with respect to factors in the physical environment, 4. Quality characteristics), and where all the actors of the sector (producers, breeders, universities and scientific profiles, regional authorities, etc.) are included.

It Is known and Internationally recognized that the ordinary genotypes selection under conventional management is effective for traits with high heritability. Unfortunately, the selected genotypes under conventional management tested with high inputs and intensive agronomic techniques are too often not suitable and adaptable in organically managed farms. This is because organic and sustainable farming management approaches and agronomic applied techniques are totally different to the conventional ones. In the organically managed farms, the biotic and abiotic components in the systems are organized in a much more complex way in order to simulate and be as close as possible to the ecosystems' structure. Organic farmers use varieties bred for conventional agricultural systems by asking derogation for the sowing. As such, during the genotype selection for the adoption in organic farming, it is necessary to consider more complex traits, and this process should be characterized by high genotype and environment interaction. In addition, it is essential that selected genotypes show superiority in the target environment for breeding success.

The specific plant, environment, and agronomic techniques characteristics should be combined for the evaluation testing; this is because of large genotype-environment-agronomic techniques interactions existing in organic and sustainable agriculture [20]. Recently, the new European regulation (Directive (EU) 2022/1647) (23 September 2022) asked the Member States to adopt a derogation for organic varieties of agricultural plant species suitable for organic production; this is because there is significant interest from the European Commission in the increasing of farming sustainability across Europe. In the variety testing system, to define the best varieties for organic and sustainable management of farms, two important aspects should be considered as a good genotypes selection approach. The first aspect is related to the traits (e.g., weed competitiveness, disease resistance and/or tolerance, adaptation to diverse soils, etc.) that are important for organic farmers and processors. The second aspect is connected to the trial environment for variety evaluation, which should give the highest probability to be the best for the key traits in organic farms [21].

In Tables 10–13, the SWOT analysis findings of VCU tests for each plant species are reported.

Table 10. Strengths, weaknesses, opportunities, and threats of VCU protocol of maize.

Strengths	Weaknesses
-Quality control of the system and product; -Add organic test.	-Lack of international standardization on methodologies.
Opportunities	**Threats**
-Quality control of the system and product; -Add organic test; -International standardization on methodologies; -Introduction of characteristics dealing with abiotic and biotic resistance/tolerance; -Involvement of special traits; -Reducing the cost of post-registration tests; -Genotyping; -Governmental support.	-Involvement of special traits; -Genotyping.

Table 11. Strengths, weaknesses, opportunities, and threats of VCU protocol of perennial ryegrass.

Strengths	Weaknesses
-Quality control of the system and product.	-Quality control of the system and product.
Opportunities	**Threats**
-Quality control of the system and product; -Addition of organic test; -"Limited" harmonization of VCU-testing; -Involvement of special traits; -Reducing the cost of post-registration tests; -Molecular studies; -Governmental support.	-Quality control of the system and product; -Organic trials are more expensive than the conventional; -Expensive molecular studies.

Table 12. Strengths, weaknesses, opportunities, and threats of VCU protocol of potato.

Strengths	Weaknesses
-Quality control of the system and product; -Degradation test.	-Period of degradation test; -Varieties are tested only in conventional management.
Opportunities	**Threats**
-Quality control of the system and product; -Add organic test; -Degeneration test for longer period; -Involvement of special traits; -Decrease cost of post-registration tests; -Governmental support; -Use of molecular markers.	-Organic trials are more expensive than the conventional.

3.2.1. Maize (*Zea mays* L.) VCU

Strengths:

Reading the responses about quality control in VCU tests, the answers and opinions are divided into two parts; several countries have understood "quality control" to refer to the "quality system", that is the management of the VCU test within a quality system. All the respondents agreed that this is Strength because it supports the process and helps to avoid or discover mistakes made during the VCU process and highlights the need for improvement. In Poland, there is a Quality Control Inspector, who has reporting responsibility to Director General. For the Eos that comprehend quality control as the quality analysis of the product, they consider the quality of the product an important characteristic to consider as part of the final evaluation of a new variety and provide comprehensive characterization of the variety. The quality control of seeds is also considered as an Opportunity.

Table 13. Strengths, weaknesses, opportunities, and threats of VCU protocol of oilseed rape.

Strengths	Weaknesses
-Quality control of the system and product.	-Lack of international standardization on methodologies.
Opportunities	**Threats**
-Quality control of the system and product; -Add organic trials; -International standardization; -Data sharing on resistance/tolerance to diseases; -Increase and differentiate the landscape of varieties available; -Using drone and artificial inoculation in disease studies; -Governmental support.	-Addition of organic trials; -Cost of organic trials and molecular studies.

The questionnaire sought opinions on the necessity of variety testing under organic conditions. Among the responding Eos, Poland conducts organic variety testing, and Estonia if needed. Even if most of the countries interviewed do not test new variety candidates under organic conditions, some of them considered taking different approaches with respect to the VCU testing, including under organic conditions, to be a means of providing better evaluation of new material. Moreover, most of the experts think that adding organic testing into VCU protocols could be a Strength, especially in the current climate change scenario where agriculture plays a key role in environmental sustainability. There are seven testing zones for grain maize and three for forage maize in France, so it is not possible to include additional organic areas for cost and experimental capacity reasons. Others outlined that nowadays the percentage of the area managed organically in Europe is still low for maize; as such, there are no concrete plans to conduct organic VCU trials. They also suggest that it is important to determine how new organic VCU testing regulations will be agreed. In addition, to test the new varieties in organic conditions, it would be essential to establish greater collaboration among European countries, which could lead to stronger network in the future concerning different aspects of trialing. Most of the respondents also considered this as an Opportunity.

Some countries suggested, as an innovation, the introduction of new characteristics that deal with abiotic and biotic resistance/tolerance, as well as new or different laboratory analysis or quality tests.

Weaknesses:

Opinions are divided on the question of whether international standardization on methodologies and protocols is necessary. Most of those interviewed think it is not appropriate to completely standardize the VCU protocol for maize because the pedoclimatic conditions are too variable across Europe. A certain degree of flexibility in testing protocols is necessary due to the individual climatic conditions of a country and demands in production. There could be some method catalog or recommended experimental setup for testing certain varieties/characteristics. The international standardization of methodology would help the harmonization of VCU testing, ensure a similar level of quality, and the unification of VCU results would generate comparable results.

Though it is not crucial to have VCU results from other countries, the interviewees believe the data of the country where the VCU test has been performed is fundamental. From the point of view of the international market, if the data are available, international comparison of the results can be made easier, and independent information about new varieties can help to better explain the differences according to the locations (Genotype $\times$ Environment interactions).

Currently, varieties are only tested under conventional cultivation in most countries. Most of the respondents do not think that this should be considered a Weakness, because there is limited organic maize production in several European countries, such as Denmark or Sweden, and results from conventional cultivation may predict, to some degree,

organic cultivation results. There are countries where breeders are not ready to work with organic varieties. Despite this, from 2023, all European countries should follow the new directive (2022/1647/EC), which will be challenging in the future. In general, this could be an opportunity if specific disease tolerance tests or quality parameters are included. For example: tolerance to different races of downy mildew (sunflower); tolerance to foliar diseases (sugar beet); tolerance to herbicides (oilseed rape, sunflower, rice); tolerance to salinity (rice), etc. Currently, a Weakness in maize VCU protocols is related to disease characteristics.

Opportunities:

Involvement of special traits such as nitrogen or water use efficiency and weed competitiveness would be an opportunity from the perspective of smart agriculture with a lower environmental impact and it would open opportunities for more sustainable varieties. However, this can lead to an increase in the cost of testing.

Regarding the decrease of post-registration test fees, different answers have been collected because these tests are performed differently in different countries. All respondents agreed that reducing these costs can be an opportunity, but that the reduction also represent Weaknesses and/or Threats, as well. According to one respondent, it seems impossible to decrease the costs of the registration processes; this is because the balance between the service provided and cost is important, and reducing the costs may impact the allocation of resources to possible new efficient assessment targets.

Respondents suggested testing the behavior of new varieties under low input or dry conditions during VCU process.

Threats:

The addition of organic trials in VCU variety testing would increase the fees, mainly due to the manual labor involved to control the weeds, but it could be useful if supported by the government.

While molecular studies would increase the costs, the respondents agreed that genotyping can be used as a complementary tool to improve the knowledge of pests and diseases resistance and must be mainly based on field experiments.

3.2.2. Lentil (*Lens culinaris* L.) VCU

The VCU tests are performed on agricultural crops. As such, there are no VCU test performed for lentil because it is a horticultural crop. Despite this, it is crucial to know if VCU tests would be a good proposition for lentils as breeders would welcome the introduction of performance testing.

The Strengths and Threats categories were not relevant due to the absence of VCU testing, but according to the respondents, this is not a weakness, because lentil is not an important crop and has no significant economic importance. One of the respondents highlighted that if the lentil is included on the list of regulated plant species, it will almost certainly be considered as a vegetable species (like *Phaseolus* sp.). The opinions are uniform about its introduction due to the lack of interest in conducting VCU tests in lentil.

3.2.3. Perennial Ryegrass (*Lolium perenne* L.) VCU

Strengths:

Respondents agreed that quality control is a strength in VCU testing programs for new grass variety candidates as it supports the process and helps to avoid or discover mistakes made during the process. For example, in the UK, data values (plot weights, % dry matter) are checked and, if necessary, a field check is also performed. If the difference is more than 10% between two replicated plots, an explanation must be provided. This can often occur due to low growth early in the season. At a higher level, the data from a trial site are compared at the UK National List level with data from trial sites across the UK. If it is not satisfactory for any reason, possibly due to adverse weather effects, etc., the data are not used.

The VCU testing programs for new candidate grass varieties In Ireland emphasizes strong quality control measures to ensure reliable results. The quality control process includes the germination test in an accredited laboratory to guarantee a minimum germination level. Then, external accredited companies perform the calibration of balances utilized for weighing seed packs. All fundamental parts of the growing technology are under continuous and stringent controls (machinery, applied sowing methods and parameters, use fertilizers and plant protection products, harvesting, drying) during the growing season and post-harvesting processing. This is achieved through strict adherence to crop protocols, which are reviewed annually by technical experts. An Assistant Agricultural Inspector conducts the analysis of harvest data, and verification is performed by an Agricultural Inspector before release, guaranteeing precision and dependability.

According to the answers, quality control was found to be a Weakness, an Opportunity, and a Threat. Quality control is a Weakness if not properly implemented, or if there are insufficient staff resources to implement it. It is an Opportunity as the VCU trialing system for grass can be improved even further. It can also be a Threat, as it needs more staff resource.

Most of the countries interviewed do not test new variety candidates under organic conditions. Currently, there is no commercial demand from farmers or the seed industry to test grass varieties under organic conditions, as grass varieties are evaluated for their dry matter yield and quality. The EO in Estonia suggested the possibility to test the variety in organic management in one site out of three, but only if the breeder orders the trial in organic management for a specific variety. This is the reason they think that it is a strength. Most of the respondents thought that, in future, this may be an opportunity, given that environmental challenges and organic cultivation are an opportunity to produce healthy animal feed. Despite this, it can be a limitation (W), as the variation in soil mineral N fertilization from organic conditions could potentially impact variety performance, and this effect may not be directly applicable to organic conditions according to an expert in this field.

As suggested by innovation in VCU testing, the growth of perennial ryegrass is influenced by various factors, including temperature and soil moisture. It would be essential to document local meteorological and soil moisture data in trials, as these data can be correlated with the growth of different varieties. This correlation becomes particularly crucial, especially at regional levels, in the context of climate change. The current trialing system is conducted under high rates of nitrogen to ensure nutrients are non-limiting. Therefore, low nitrogen trials should be implemented in the future as a step towards more sustainable input use, while also being more reflective of actual on farm grass sward management to encompass various grassland-based enterprises.

Weaknesses:

According to the respondents, the lack of international standardization is not a weakness. Despite this, they agreed that international standardization is important, but due to the differences between climatic conditions of counties, the conditions for grass production are very specific, so it would be very hard to internationally standardize some parts of methodologies. Each country recognizes their best experience and has the best knowledge of their conditions and possible values and should be able to set standards that are best for them. The expert from Sweden suggested determining recommended minimum values for a key set of parameters, which would help the harmonization of VCU testing. In the case of quality, although protein content is a varietal characteristic, it is also largely determined by the time of cutting. The harvested crop of forage plants is usually not marketed. For this reason, establishing a minimum value for protein content, etc., would also not be meaningful.

Concerning protocol standardization, most respondents think that each country needs its own protocol suited to local conditions and demands in production. From another point of view, there are fewer breeders of perennial ryegrass than of wheat, for example, and end-use is also similar in the individual countries. For this reason, it would be appropriate to

partially standardize the VCU testing methodology. Moreover, if varieties were evaluated across standardized protocols, data would be more comparable and would be less likely to be undermined or questioned by breeders and academic institutions.

According to the responses, it is not crucial to have data from other countries, but it would be useful; the interviewees consider the data concerning the country where the VCU test has been performed as essential.

In the case of conventional management practices used in VCU variety testing (as Weakness), opinions are different. This is not regarded as a weakness, because conditions differ very little between organic and conventional farming. It can also be a strength because varieties are tested for what they will be ultimately used for, which in our situation is for conventional management to achieve higher dry matter yields and higher quality. Those Eos who consider this aspect a weakness think that it is also an opportunity. In Austria, a large portion of grassland is managed organically. The VCU test should reflect actual agricultural use. The availability of nutrients (particularly nitrogen) differs from farm manure (e.g., slurry) to inorganic mineral fertilizers.

The lack of national and international priority of characteristics during the VCU test is not a weakness of the system for all the countries. Priority of characteristics is possible at the national level, but it is very difficult on the international level.

Opportunities:

The involvement of special traits could be an opportunity—mainly in organic conditions—but would increase the costs of the VCU process. Special traits that are considered being relevant (such as stamina/persistence and winter hardiness) are already being assessed in Sweden and the UK. Nitrogen use efficiency and weed competitiveness would be seen to be more relevant in other crops, but N use efficiency will become increasingly important in relation to NO_2 emissions. Certain characteristics are complex and can only be examined under specific conditions that are challenging and/or costly to replicate in trials. Efforts should be evaluated in relation to the practical significance of the trait. In Denmark, special traits are assessed upon the applicant's request. More information is usually better for decision-making for stakeholders.

Different answers were collected regarding the possibility of reducing the cost of post-registration tests because these tests are performed differently between countries. All agree that low costs are always an advantage, but some Eos are making effort to decrease the post-registration costs. For example, in Denmark, pre- and post-registration trials are combined, which minimizes the costs. In most of the responding countries, such as Austria, no separate post-registration trials are carried out for perennial ryegrass. Instead, after variety registration, the varieties are assessed for another year to determine their persistence. The trial is only terminated after this assessment.

Threats:

Every country agreed that implementing additional organic trials, which are more expensive than conventional trials, is a threat, although most of them do not conduct organic VCU trials on grass varieties. Only Estonia can conduct organic VCU test (if needed), and their opinion is that the price would probably be the same. If organic tests were needed, it would be important that they be supported by the government.

Another aspect that should be considered is an index or score for new varieties to allow better decision making and 'future proofing' varietal selection; for example, this could take the form of combining the DUS with genotyping and ecosystem service and soil carbon capture potentials and profitability.

The Eos agree that it is not important to apply any molecular studies during VCU testing of grasses.

3.2.4. Potato (*Solanum tuberosum* L.) VCU

Strengths:

Quality control of both system and product is important and necessary in potato VCU testing. The control of the nutritional value of potato tubers is of great importance; the

role of starch and reducing sugar content determines the end use of the tuber. Testing of protein content can be an opportunity. Quality control of the system helps reduce errors and highlights process weaknesses, so it is also an opportunity. Moreover, it supports the process and helps experts to avoid or discover mistakes.

Four countries (Austria, Estonia, Poland, and France) can test varieties in organic conditions. Estonia has one site out of three, but this is used only if the breeder requests the test for a specific variety. In Austria, early to medium-early maturing varieties can be placed in two out of six organic sites, while medium-late to late maturing varieties can be tested under organic conditions in one out of six trials. Most of the respondents agreed that variety testing in organic condition is an opportunity; this is because those new potato cultivars that are resistant/tolerant to several pathogens should be tested in organic condition. According to the Hungarian expert, it can be a threat due to the growing costs and sensibility of abiotic factors. The degeneration of potato in Hungary is tested, which is a strength, but in the opinion of the expert, this should be tested for a longer period (W and O).

Weaknesses:

Respondents who think that the lack of standardization on methodologies and protocols is a weakness of the VCU tests justified their answer by saying that the results would be comparable and could promote the correct evaluation of different potato cultivars. Since climatic conditions are very different across Europe, it would be difficult to internationally standardize some parts of the methodologies. Every country knows their own best experience and knowledge of their conditions and possible values and should be able to set standards that are best for them. This is the reason why most responding countries do not consider it as a weakness. The respondents agreed—except Slovakia and Hungary—that the lack of available data is not a weakness, but this is a barrier for the future development of VCU testing.

Varying opinions were received on whether organic testing is necessary in potato VCU testing. Performance of new (multi-resistant/tolerant) potato cultivars in organic conditions would be very valuable information for breeders, farmers, etc., but organic tests would increase the cost of the evaluation process. Results obtained in conventional conditions can predict the suitability for organic production because conventional VCU methods contain a lot of useful disease tests; as such, it is not a weakness, but a strength or opportunity.

Opportunities:

Involvement of special traits is an opportunity for post-registration and organic VCU trials, and if the knowledge gained is justified, it can be an opportunity, especially if breeders are willing to meet the additional costs. In addition to a better and specific evaluation of new varieties beyond the classic evaluation parameters, it is an opportunity to increase and differentiate the landscape of varieties available to farmers. Decreasing the cost of post-registration testing is an opportunity and low costs are always an advantage. In Denmark, trials are inherently expensive due to the amount and cost of labor involved. The demand for post-registration data is limited compared to other crops since much of the production Is conducted on contract or the product Is sold beforehand. It would be a great opportunity to support post-registration tests by farmers' organizations and food industries, as well as by public funding. Use of molecular markers can be an opportunity when seeking to evaluate the resistance characteristics to pathogens, and these tests have the potential to have a big impact on identification of varieties, international trade systems, and plant breeders' rights systems.

Threats:

Including more trials or studies in the VCU testing process would increase the cost, which is a threat, but with governmental support it would become an opportunity.

3.2.5. Oilseed Rape (*Brassica napus* L.) VCU

Strengths:

Quality control, as with any other plant species, safeguards quality and highlights the need for improvement. Most of the respondents agreed that this is an opportunity, although this may require more investment (especially in staff).

Most of the countries interviewed do not test varieties in organic conditions as there is no current need, but Eos can conduct organic tests upon request from the applicant. Organic evaluation of new varieties that do not express their potential in the traditional network may be an opportunity. Respondents highlighted that oilseed rape is a difficult crop to cultivate organically due to the high level of threat from pests and diseases.

According to an expert from Italy, an international standardization would be desirable, both to evaluate the new variety with the same parameters and to have common protocols between the various countries carrying out the trials.

Weaknesses:

The lack of international standardization on methodologies were considered to be partially a weakness and also partially not. It was considered Not to be a weakness because each country has their own climatic conditions and specifics needs, meaning that international standardization for minimum values is not useful. It is hard to compare such values across Europe due to different agroclimatic conditions. It was considered to be a weakness because it could be useful to share information on standard methodologies. In Austria, VCU tests are conducted to examine the oil and glucosinolate (which is harmful to both humans and animals) content and, more recently, the protein content. A variety with a very low oil content is not valuable and is not registered. It is not necessary to set a limit value. An international limit value has been set for erucic acid and glucosinolates and it should be the same in all EU countries. The opinion of the Slovakian expert coincides with this suggestion.

While the responses to the question about the international methodology were not unanimous, respondents agreed that the lack of international standardization in protocols is not a weakness. Their opinion is that each country needs its own protocol suited to the local conditions and demands in production.

The opinions also varied regarding the availability of data. Some respondents said that it is not necessary to share the agronomic data between the different countries. Agronomic data show the potential of varieties in one country that may not necessarily be useful in another country. However, the majority of respondents believe that, for example, data on resistance/tolerance to diseases would be important and useful for comparison and would give more complete information about the variety. Sufficient data is the basis for good quality variety testing.

The opinions are also different between the countries regarding national and international priority of characteristics during VCU testing. Those respondents who answered that this is not a weakness said that the priority of characteristics differs on a regional basis. More important and less important traits are recognized. A slightly different priority is justified (e.g., winter hardiness is more important in Northern Europe than in Southern Europe). According to the Austrian expert, there are plans to describe the varieties in terms of their resistance to Turnip Yellows Virus (TuYV) in the future.

Opportunities:

A better and specific evaluation of new varieties beyond the classic evaluation parameters is an opportunity to increase and differentiate the landscape of varieties available to farmers. Furthermore, it is a challenge for organic breeders to expand their portfolio of quality organic varieties and for farmers to increase organic growing areas. The respondents also mentioned additional opportunities, such as using drone technology to determine phenological traits and diseases and artificial inoculation in disease studies or breeding of varieties tolerant to increasing stress factors and low nitrogen requirements.

Threats:

The cost of organic trials and molecular studies are the main threat factors. Organic trials are expensive for oilseed rape. This is due to the substantial number of trials not being of sufficient quality to be used due to heavy pest infestations. Molecular studies are

mainly related to resistance genes and chemical properties, which could provide important information on disease resistance/tolerance, etc. of varieties. Both organic trials and molecular studies should be supported by the government, but according to the expert from France, in the case of organic trials conducted over the long term, the system of assessment for organic production should be self-financed. The organic farming sector could contribute to the financing.

Distribution of answer frequencies concerning the most important questions are reported in Figure 7.

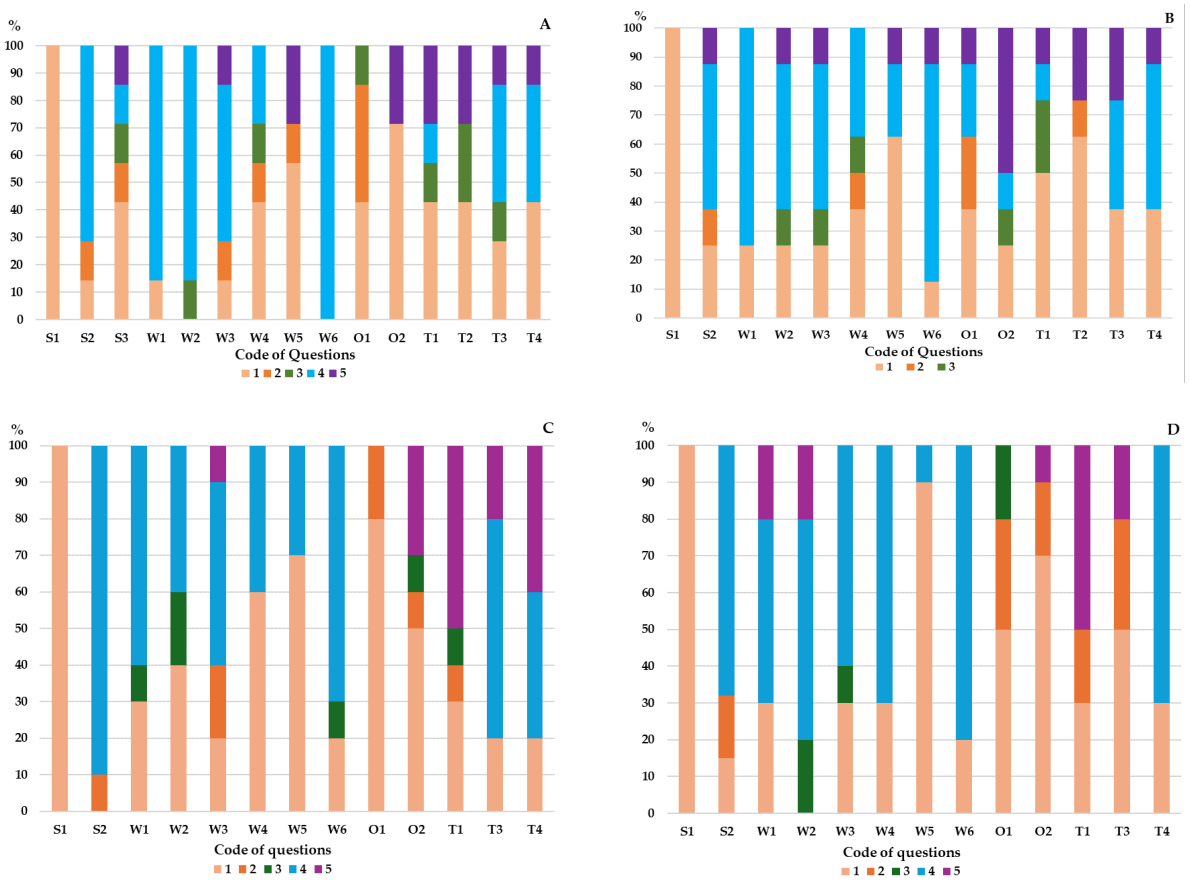

Figure 7. Frequency table of answers to the SWOT questionnaire regarding VCU tests of maize (**A**), potato (**B**), perennial ryegrass (**C**), and oilseed rape (**D**), where S, W, O, and T mean strengths, weaknesses, opportunities, and threats, respectively. Code of questions: S1: Quality control: Do you consider quality control a Strength in your scientific knowledge? S2: Varieties are tested in organic conditions: Are varieties tested in organic management? S3 (in the case of maize): Do you think adding organic test could be a S? W1: Lack of international standardization on methodologies (e.g., minimum values for content in protein, sugar, fat, etc.): Do you think this is a Weakness? W2: Lack of international standardization in the protocols: Do you think this is a Weakness? W3: Lack of available data. Do you think this is fundamental? W4: Varieties are tested only in conventional management: Do you think this is a Weakness? W5: Number of organic trial locations is low: Is it correct in your Country? W6: Lack of national and international priority of characteristics during the VCU test: Do you think this is a Weakness? O1: Involvement of special traits (e.g., weed competitiveness, nitrogen use efficiency, etc.). Do you think is this an Opportunity? O2: Decrease cost of post-registration tests: Do you think is this an Opportunity if applied? T1: Organic trials are more expensive than the conventional ones: Is it correct in your Country? T2 (in the case of potato and maize): If yes, do you think it should be supported by the government because it could become an Opportunity? T3: Expensive molecular studies: Does molecular testing have a reason to be applied? T4: If yes, do you think it should be supported by the government because it could become an Opportunity? Categories: (1)—Yes; (2)—Yes, conditionally; (3)—Yes, partly; (4)—No; (5)—Not relevant.

3.3. Development of SWOT-Strategies for DUS and VCU Plant Variety Tests

3.3.1. SWOT-Strategies for DUS Protocols

Based on the results, two SWOT strategies could be established: "SO" and "WO" (Table 14). "ST" and "WT" strategies could not be developed due to the lack of threat factors. This could mean that DUS variety testing is a well-functioning system, containing possibilities and innovations. The weakness of the system can be determined as the lack of objectivity for visually registered characteristics, but the solution is the organization of training.

Table 14. Established SWOT strategies for DUS protocols.

		Internal Origin	
		Strength: -DUS test conforms to all international accepted standards; -Scale used for expression level of characteristics covers all possible states; -Complete characteristics list; -Characteristics are sufficient to describe and distinguish new varieties.	**Weakness:** -Some characteristics are difficult to assess objectively; -Scale used for expression level not objective enough.
External origin	**Opportunities:** -Data sharing of the variety description; -Introducing of new techniques; -Authentication of seed test could be carried out by molecular markers; -Use of SNPs or other genetic markers; -Create database which can monitor genetic diversity and drift of a species.	**SO-strategies:** -Create the conditions for the use of SNPs or other genetic markers; and innovative techniques (SO1); -Develop new regulations of the use of new tools in DUS variety testing (SO2); -New government support programs (SO3).	**WO-strategies:** -Provide effective and continuing training programs for DUS and crop experts and (WO1).
	Threats: -GMO (T1)	**ST-strategies:** no strategy could be created	**WT-strategies:** no strategy could be created

3.3.2. SWOT-Strategies for VCU Protocols

Quality control, considered a Strength of VCU testing, is an important part of VCU testing, with several possibilities. It has a detailed guide to the variety testing and has adequate quality control documents. Introducing more quality analysis (SO1) and application of quality inspectors (SO2) with reporting obligation (just like in Poland) can be an opportunity. Quality control can be a weakness if not properly implemented or if insufficient staff resources to implement it (WO1). In many countries, there has been no variety testing in organic conditions so far, but this may change in the future. It could be possible to add organic trials in the network (SO3)—depending on the plant species—and determine the value of the variety by using the network's average result (mix of conventional and organic trials). Standardization of the most important characteristics (even a few) should be defined (SO4; WO2) and then the results should be reported in the Catalogues and registers. In this way, the consumer could be free to choose the varieties objectively (Table 15).

The difficulty in the harmonization of VCU tests is the range of different disease and climatic stress tolerances for the same cultivar. National multilocation variety trials and the establishment of different agro-climatic zones (ACZ)—as in the InnoVar project—are solutions that can be used to enable identification of varieties that meet diverse agronomic and consumer requirements. The most important aim of VCU trials—focusing on the benefits of the varieties—is to support farmers in achieving greater efficiency, profitably, and sustainable management. During the project implementation of a harmonized VCU, the "InnoVar-protocol" was developed and applied in VCU trials in 14 different European trial locations across 10 countries and 5 ACZ. The results of the project would form the basis for the development of new, integrated, user-friendly systems using molecular, genomic,

phenomics, and machine learning techniques to increase and improve the efficiency and accuracy of European crop variety testing and on-farm decision-making.

Table 15. Established SWOT strategies for VCU protocols.

		Internal Origin	
		Strength: -Quality control of the system; -Varieties are tested in organic conditions; -Lack of international standardization on methodologies and protocols (depending on plant species).	**Weakness:** -Quality control of the system; -Lack of international standardization on methodologies and protocols (depending on plant species); -Lack of available data; -Higher cost of post registration test.
External origin	**Opportunities:** -Quality analysis of grain; -Varieties are tested in organic conditions; -International standardization on methodologies and protocols (depending on plant species); -Involvement of special traits; -Decrease cost of post-registration tests; -Involvement of molecular studies.	**SO-strategies:** -Introduction of more characteristics in the grain analysis; -Quality Control inspectors; -Introduction of organic trials; -To consider the possibility of harmonization of each plant species.	**WO-strategies:** -Provide effective and continuing training programs for DUS and crop experts; -Standardization of some aspects of the different VCU protocol (depending on plant species); -Post-registration test support.
	Threats: -Quality control of the system; -Expensive molecular studies.	**ST-strategies:** -New governmental support programs.	**WT-strategies:** no strategy could be created

4. Discussion

It is well known that plant breeders constantly face new challenges and must set new goals during the development of new varieties. Before introducing new varieties into cultivation and commercial scale production, the varieties must be examined thoroughly and in accordance with strict regulations in order to make recommendations to the growers with sufficient information [22]. However, methods and tools for studying new varieties also require state-of-art development. Several new methods can be used for evaluating new plant varieties alongside conventional tests e.g., molecular markers or sequencing-based methods to identify genotype or to perform DUS test [23,24]. Evaluation of new genotypes in VCU and DUS tests being applied officially would be more reliable after introducing new types of tests, including new characteristics [22,25].

Within the framework of the InnoVar project, we looked for the possibilities of modernizing the VCU and DUS protocols and developing new test methods and potential—even crop-specific—characteristics.

Crop traits, which can be physiological or phenological, are parameters that define a plant variety, including productivity and the ability to maintain productivity under changing conditions (yield stability) [22]. Yield traits (e.g., number of pods per plant, thousand grain weight, etc.) also play important role in VCU testing as well as morphological traits in DUS testing [26–28]. Based on the answers to the questionnaire, we can state that the majority of the traits proposed for inclusion in the testing procedure are mostly of a physiological nature, e.g., biotic and abiotic stress resistance/tolerance, nitrogen and water utilization ability, stamina, winter hardiness, suitability for organic cultivation.

A SWOT analysis is a method used to scan strengths, weaknesses, opportunities, and threats of businesses to establish a strategic plan or roadmap [29,30], which can help in decision-making processes. Application of SWOT analysis alone or in combination with another method, such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [6] or Analytic Network Process (ANP) [31], can help determine the best strategy for the studied organization. The SWOT analysis is versatile, revealing strengths and opportunities in various contexts. It is used in benchmarking to identify best practice

opportunities and threats, in industry analysis to understand market opportunities, in situation analysis to evaluate customer trends, costs, and competition, and in scenario planning to contemplate potential future scenarios [32]. SWOT analysis can be successfully performed in the agricultural sector to evaluate agricultural businesses, managements, economics, and farm operation systems [30,33–35] and it proved to be a useful tool to build different strategies analyzing the assessing the correlation between agricultural food insecurity, demand and food supply, and understanding the specific connection of this relationship to the context of the COVID-19 pandemic [36]. Conducting SWOT analysis for evaluation of the plant variety testing system is not widespread but is a useful method. Findings of a case study highlight the importance of the post-registration variety test scheme in Poland and its impact on agricultural practices, variety selection, and the overall agricultural economy. The study also emphasizes the significance of diverse funding sources and the potential for increasing the scope of variety testing to benefit farmers and agricultural productivity [3]. As a part of a European Project, LIVESEED [37], which discussed the inclusion of organic VCU testing descriptions in countries where such trials are conducted, emphasized their close connection to organic pre- and post-registration trials. Additionally, it highlights the presentation of information, including selected examples of post-registration trials, through SWOT analyses, providing a comprehensive overview.

Involvement of special traits to the variety testing process, such as weed competitiveness and nitrogen or water use efficiency, is clearly linked with sustainability objectives and generates more information for sustainable production. All suggested innovations and opportunities found in our study focused on enhancing the efficiency of food and agricultural systems, supporting the resilience of agricultural systems to adapt to rapid changes and extreme conditions, and encouraging and maintaining the sustainability of agriculture.

This study should be shared across Europe at different levels, both political and technical, as it constitutes a critical analysis by key actors of the agriculture system on the procedure to release new varieties into EU territories, especially in this time of change. Indeed, the European Commission recently published a proposal for a new regulation of the European Parliament and of the Council on the production and the marketing of plant reproductive material in the Union (Brussels, 5 July 2023). In this time, several institutions across Europe at different levels of governance are reviewing the proposal with the aim to provide their input on the new regulation. For example, in Italy, in the last year, the Ministry of Agriculture has involved different actors from the seed sector (trade organizations, examination office, experts) in a critical discussion on the new legislation. In the proposal in Section 2, dedicated to the variety registration, the new concept of sustainable cultivation and the uses (VSCU) for the agronomical evaluation of the variety are introduced. It is specified that the new material should be tested not only for yield but also for yield stability and yield under low-input conditions [38]. For this procedure, it will be crucial to consider the tolerance/resistance to biotic stresses, including plant diseases caused by nematodes, fungi, bacteria, viruses, insects and other pests, and abiotic stresses, including adaptation to climate change conditions and the more efficient use of natural resources, such as water and nutrients. The reduced need for external inputs, such as plant protection products and fertilizers, will be considered a positive feature. Interestingly, some of these topics were also considered in the SWOT analysis in which the respondents, principally examination offices and breeders, identified new characteristics or methods with the aim of reaching a more precise and a deeper evaluation of the new varieties. They proposed special trials, including nitrogen and water use efficiency and weed competitiveness. In addition, involving the organic cultivation test for the agronomical evaluation of varieties for all species are considered to be an opportunity [22]. Similarly, we also found that organic testing was considered to be an opportunity by respondents e.g., in the case of oilseed rape.

In the questionnaires, the interviewed EOs shared their thoughts on the use of new technologies (phenomics, genomic) for both DUS and VCU testing. Drones could help in

the assessment of several characteristics and help achieve greater objectivity, specifically in DUS testing. Indeed, in the questionnaires, it came out that some non-measurable characteristics, listed in the protocol in force for the species considered, are difficult to estimate objectivity. Several other studies also highlight the importance and necessity of introducing machine learning to standardize phenotyping in regard to different biotic and abiotic stresses [39–41].

The molecular background of important agronomic traits can be studied with the use of molecular markers and, combined with modern technology, new methods can be easily established [42]. In our study, the molecular markers were proposed mainly in relation to resistance genes and to quality features of the varieties for the evaluation of agronomic characteristics of the variety. In DUS testing, for the management of the reference collection, molecular markers could be used as a central tool for evaluating the distinctness of the candidate variety. Notably, most of the respondents considered the use of molecular markers as both an opportunity and a threat, the latter due to their high cost. The introduction of molecular markers in variety testing is crucial for the accuracy and effectiveness of the tests, and, beyond this, they could also help to identify new characteristics that could be considered for both DUS and VCU testing, thereby reducing the cost of the trials and making new traits for new varieties more suitable for regenerative agriculture.

5. Conclusions

Technical developments, climate change, changing consumer needs, including the detection of GMO organisms, and new genomic techniques (NGT) for growing plants necessitate the innovation of methods in plant variety testing. For the development of new methods to be more effective, experience gained on a wider scale is necessary. The questionnaires sent to several countries help reach this aim, which seeks a new direction, opportunity, and strategy with the help of the analysis of the weakness and strength of the current methods. This can then be integrated with the innovation results, and the development of the new methods can be built on the basis of all the results.

As the output of this study, the SWOT analysis can be adopted to achieve the stated goals, and the introduction of new characteristics (e.g., cold tolerance) and new testing methods (molecular markers, precision techniques) become relevant. In the future, it is necessary to map the possibilities inherent in the variety testing methods of the major plant species of all EU member states and to create the necessary the financial conditions for this to occur. This study displays the results of the SWOT analysis of DUS and VCU testing and provides an alternative strategy to innovate the protocols. This work contributes to better understanding that the varieties performing well in organically managed farms have potential barriers for identification if variety testing is not carried out under organic and sustainable farming rules addressed to high levels of sustainability.

The SWOT analysis implemented on the present variety testing processes (DUS and VCU) is an important and useful document that could help in the technical debate on the new proposal or in general on the innovation on the process for registration and protection of new varieties in Europe. As such, it will be disseminated among all Member States and associations involved in variety testing and protection (CPVO, UPOV, EU-VCU network) across Europe as one of the final goals of the InnoVar project.

Author Contributions: Conceptualization, N.M.-D., R.M., S.M.U. and L.B.; methodology, N.M.-D., R.M., S.M.U. and L.B.; formal analysis, N.M.-D., R.M., S.M.U., L.B., K.M.-T., E.N., P.C. and T.B.; investigation, N.M.-D., A.G., R.M., S.M.U., L.B., K.M.-T., E.N., P.K.H., P.C., M.A. (Mohamed Allam), M.A. (Mariam Atait) and T.B.; writing—original draft preparation, N.M.-D., K.M.-T. and H.B.; writing—review and editing, N.M.-D., K.M.-T., R.M., H.B., M.A. (Mohamed Allam), M.A. (Mariam Atait), S.M.U., E.N., T.B., P.C., L.B., P.K.H. and A.G.; visualization, R.M. and K.M.-T.; supervision, N.M.-D., R.M. and L.B.; project administration, H.B. All authors have read and agreed to the published version of the manuscript and have contributed substantially to the work reported.

Funding: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818144.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: Author Preben Klarskov Hansen was employed by the company Tystofte-Foundation. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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