What makes a plant science manuscript successful for publication?

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Perspective

What makes a plant science manuscript successful for publication?

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Abstract. Dissemination of new knowledge is arguably the most critical component of the academic activity. In this context, scientific publishing is a pinnacle of any research work. Although the scientific content has always been the primary measure of a paper's impact, by itself it may not always be sufficient for maximum impact. Good scientific writing and ability to meet priority characteristics of the target journal are essential, and inability to meet appropriate standards may jeopardise the chances for dissemination of results. This paper analyses the key features necessary for successfully publishing scientific research manuscripts. Conclusions are validated by a survey of 22 international scientific journals in agriculture and plant biology whose editors-in-chief have provided current data on key features related to manuscript acceptance or rejection. The top priorities for manuscript rejection by scientific journals in agriculture and plant biology are: (1) lack of sufficient novelty; (2) flaws in methods or data interpretation; (3) inadequate data analyses; and (4) poor critical scientific thinking. The inability to meet these requirements may result in rejection of even the best set of data. Recommendations are made for critical thinking and integration of good scientific writing with quality research. These recommendations will improve the quality of manuscripts submitted for publication to scientific journals and hence improve their likelihood of acceptance.

Additional keywords: experimental design, manuscripts, publishing, scientific writing, statistical analysis.

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Introduction

Research is not completed until it is published. Scientific writing is hard work, and only very few people are born as 'natural writers'. Many researchers and post-graduate students also lack confidence in their writing skills. These qualities, however, can be developed. So, what does it take to make a good paper? At what stage should one start the writing? How can this be done in a most efficient way? What journal should be targeted? And what is necessary for the successful completion of a manuscript that will be accepted for publication by the targeted journal? Answers to these questions support the view that only the publication of results will make the research effort worthwhile and a part of the scientific knowledge (Heard 2016).

A history of scientific writing

The Royal Society of London was established in 1660 to improve natural scientific knowledge and lay the foundation of good scientific writing. Founding members including Thomas Sprat and Robert Boyle highlighted the importance of a plain, accurate, clear and concise writing style. Harmon and Gross (2007) describe the history of the structure of the scientific paper. Although the Royal Academy of Sciences in Paris was the first to publish book reviews and news in science in the *Journal des Sçavans* (Journal of the Learned) in 1665, it also included other works in theology, law and anything that might be of public interest. Later that same year The Royal Society of London published *Philosophical Transactions*, which is credited as being the first pure 'science' journal (Harmon and Gross 2007).

The Founders of The Royal Society suggested that scientists aim to write lucidly and concisely; a goal towards which scientists have strived ever since. Following the foundation, the 'Introduction', 'Materials and methods', 'Results' and the 'Discussion' (IMRaD structure) was developed in the 1830s and '40s, and in the 1950s the structure was expanded to include an 'Abstract'. This format is not set in stone, but the general structure gives readers efficient access to the various categories of information presented in a scientific paper.

Scientific writing is different from scientific publishing

All scientists are capable of scientific writing, although some clearly write better than others. There are many texts about this subject (e.g. Harmon and Gross 2007; Lindsay 2011; Gastel and Day 2016; Heard 2016), and numerous university websites offer lengthy guidelines to assist authors in the preparation of scientific documents (e.g. Barrass 1978; University of Leicester 2009; University of Leeds 2019). One approach suggested for new authors used by Heard (2016), supports that 'writing is hard for everyone', and emphasises that scientific writing is a craft that can be improved with practice, discipline and various diverse strategies. A comprehensive text including the history and definitions of a scientific paper, text preparation guidelines, table and figure formats, manuscript reviews and publishing guidelines is presented by Gastel and Day (2016). Such texts deliver one key message: scientific writing can be complex. For example, professional editors sometimes speak of checking for the '4 Cs': clarity, coherency, consistency and correctness. And there may be as many as '8 Cs': compliance (i.e. journal guidelines), completeness, composition, correctness, clarity, consistency, conciseness and courtesy (Gastel and Day 2016).

There are many texts on scientific writing that focus on the scientific writing style, but fail to address the many possible reasons why a manuscript may not be suitable for publication. For some, scientific writing may be challenging enough, but scientific publishing is even harder. Our paper highlights the major difference between scientific writing and publication. One of the most noticeable differences is that scientific publication always implies a 'novelty'. Thus, even excellence in writing per se cannot compensate for the paucity of novel ideas and other key attributes of a scientific paper. Some of these attributes evolve before the writing begins – at the stage of experimental planning, data collection or analyses and interpretation.

A good scientific paper cannot be written (or is worth writing) unless the data and ideas are assembled in a logical way to tell the reader the story, and the figures and tables clearly narrate the essential results. Importantly, the logic of presentation does not often resemble the actual chronological course of events that occurred in completing the research or theoretical thesis. This is exemplified by an anecdote from Sir Rutherford (Bob) Robertson – Australia's most distinguished, influential and respected plant scientist – who had a story about writing scientific papers that went as follows: 'A scientific paper is like a dark house that several people are trying to get into. They don't have the key, and they are all fighting to get in. So they break windows; punch and hit each other on the head. Then they crawl through the windows. Someone finds a light, and they switch it on. Then they straighten up the house, open the door, and they say, 'Look how wonderful we found this house!'. This is not usually how the story or real sequence of experimental research happens: it is an artefact of paper construction (H. Greenway, pers. comm.).

Credentials, objectives, and approaches

Here we focus specifically on the preparation of manuscripts for publication in agricultural and plant biology journals. However, most of the principles and information discussed here are also relevant to the preparation of manuscripts for publication in other scientific disciplines. There are likely to be specific details in other and related fields that are not covered here, but these will be relatively minor compared with the common aims and techniques that we all use as scientific writers.

As authors of this paper, we have been collectively involved in scientific writing for 171 years in various roles: as authors, journal editors, reviewers, panel members for various funding bodies and postgraduate student supervisors. As a result, we have written, guided and critically reviewed thousands of scientific journal manuscripts, book chapters, reports and research grant proposals either alone or together with teams of scientists and students, both nationally and internationally. This experience has enabled us to compile a summary of key attributes for scientific publications in agriculture and plant biology.

When starting to write a manuscript, the first decision is which journal to aim to publish in. The chosen journal should be one that publishes work within the area of research about which the manuscript it to be written. It is helpful to check the list of associate editors, as one of these will be handling the paper when it is submitted. Alternatively, authors could make a list of 10 scientists that might read (and cite!) your paper and see which journals in which they frequently publish.

Author Guidelines: how essential are they?

Known under different names (e.g. 'Information to/for Authors'; 'Instructions for Authors'; 'Author Information Packs'), these instructions vary immensely between different scientific journals, from the equivalent of just few to 31 printed pages (as shown in our survey of 22 scientific journals presented here). Apart from providing specific technical requirements or styling for preparing the manuscript (e.g. font size, line space, figure resolution, reference style), these guidelines are also critical to match the journal's profile with the set of would-be-reported data. Unfortunately, this aspect is often ignored by inexperienced authors.

Although all journals have a clause that submitted manuscripts are accepted for consideration with the understanding that the work is 'original' or 'novel', the definition of novelty varies drastically between journals. The legal definition of the term 'novel' (i.e. that no part of the work has been published previously, and that it is not under consideration for publication elsewhere) is only the first half of equation. All high impact journals associate 'novelty' with an extent of the contribution to the field. Most good journals emphasise this point by providing clear instructions to their referees. As stated in the instructions to one journal, 'We want to publish papers with novel and original content that move the subject forward, *not papers that report incremental advances* or findings that are already well known in other species. . ..' [emphasis added]. This is further illustrated by the wording of the immediate reject letter for authors submitting to journals such as *Functional Plant Biology*: '*Functional Plant Biology* is a broad-based interdisciplinary plant science journal, with papers presenting novel results that are not limited to a localised or specialised angle'. To our great surprise, many authors fail to understand or tend to ignore such requirements. As a result, a large percentage of the manuscripts are not even entering the review process, but are immediately rejected, with a lack of novelty being one of the key reasons for rejection.

Another critical requirement specified in Author Guidelines – but often ignored by the authors – is the scope of the journal. The journal scope is one of the most important descriptions to be considered in the selection of a target journal for manuscripts, as many plant science journals put a very specific requirement for the submitted work: that it should provide a mechanistic explanation for the reported observations. However, in the race for a higher impact factor, authors tend to overlook this requirement, and submit papers based merely on observations. It should be clearly understood that such work is also important and worth publishing; however, authors of observational papers should be realistic in their expectations and select appropriate journals that do not have the above requirement.

Another issue that is mentioned in the Author Guidelines but not often taken seriously by authors is a requirement to list several suggested referees. The choice of two or three, independent, expert and accessible referees is essential, and helps to create the impression that the authors know their field of work. Listing colleagues, for example, rather than a world authority in the field, as a referee, will reveal a lot to the editor about the authors and possibly about the quality of the manuscript. In a lay term: nominating your buddies as referees is simply counterproductive.

Further, each journal has its own process for manuscript refereeing, production, proofing and handling charges. In recent years, the latter has become a common decisive point in selection of a target journal. All journals with an Open Access model charge publication fees (see below), but the quality and rigour of the review process may differ dramatically. The 'just pay and publish whatever you like' model employed by many predator journals will do little justice to your work.

The importance of impact factor is a controversial and hot discussion topic in the scientific community. Impact factors indicate how often all the papers in a journal are cited on average – not how often your particular paper will be cited. Furthermore, the average citation does not indicate other impacts that your paper may have, including the quality of the science, the purpose of the research (Lindsay 2011) or impacts on policy or practices (Gastel and Day 2016). Further, impact factors should not be compared across different fields because each field often has different citation practices. More recently, 'article-level-metrics' (Tananbaum 2013) and even 'altmetrics' (a social web-based measurement; Barnes 2015) have been employed to quantify the impact factor of specific publications.

Key attributes of a successful manuscript

So what makes a manuscript successful and helps the publication process to be smooth and painless? To answer this question, we have conducted a survey of 22 editors-in-chief of leading international journals in the field of agriculture and plant biology (Table 1), and a summary of the key characteristics for a successful publication are reviewed below.

Novelty and significance

These two criteria are arguably the most important in securing acceptance for publication. Undoubtedly, they are not likely to be enough by themselves, but without meeting the criteria to an acceptable standard (which is specific to each journal), a manuscript has no chance of being published. Journal editors, reviewers and readers look for something new – a new gene, a new metabolite, a new function, a new solution for crop production on hostile soils. Both the novelty and significance should be clearly emphasised in the paper, usually in the Abstract and in the summary paragraph at the end of Introduction. It is also critical to relay a clear message about the novelty and significance of your work to the handling editor via the submission letter. The failure to do this can often result in an immediate rejection. The importance of the submission letter can be illustrated by the comment of one of our colleagues: 'When I submit a Nature paper I usually spend as much time writing the submission letter as the paper itself'. Many authors also forget that the novelty of the work cannot be 'introduced' at the writing stage. Novelty needs to be incorporated in the experimental plan before the work is commenced. Good writing style cannot substitute for the lack of ideas.

Critical scientific thinking

Critical scientific thinking is needed at three stages of the project. First, when clarifying the importance of the project and the need to conduct the work. Second, when deciding on the type of experiment, and the methods and materials needed to conduct the project. And third, when analysing the results with an objective and critical attitude. Many projects set up clear hypotheses and are designed to test them. The answers can be 'yes', 'no' or 'unclear'. The 'yes' result can be published, the 'no' result could be equally important but, in most cases could not be published on its own. Some explorative projects do not carry an explicit hypothesis, for instance, those that look for genetic diversity across a given plant species or for DNA sequences that associate with an environmental variable. From these broad studies a hypothesis can be formed for more focussed research, and an experimental design developed for future studies.

Adequacy of the research data

Deciding on whether the dataset is complete and substantial enough for publication in a top journal can be difficult. However, the quantity of presented data does not guarantee either its novelty or significance. As a rule of thumb, the amount of experimental data should be enough to justify all the conclusions made in an unequivocal manner. Some journals may have more specific and explicit requirements on the number of biological repetitions (e.g. as in 'omics' studies),

Table 1. Scientific journals responding to a survey on key characteristics for publishing

The scientific journals listed here cover the fields of agriculture and plant science and all responded to a request to provide the survey data; individual replies have been kept anonymous. Abbreviations: IF, impact actor in 2018 (JIF 2018; https://apps/clarivate.com/mjl-beta/search-results); SJR, Scimago Journal & Country Rank values (SJR 2018;). Data for each journal were accessed on 25 April 2020. Data for publisher country are taken from JIF (2018)

No.	Journal	IF	SJR	Charges[A]	Open Access fees[A]	Issues per year	Publisher (country)
1	*Molecular Plant*	10.81	4.27	2200	3700–5200	12	Cell Press, USA (China)
2	*Plant Physiology*	6.31	3.71	800–2100	0–1500	12	American Society Plant Biologists, USA
3	*Frontiers in Plant Science*	4.11	1.69	–	1850–2950	Irregular	Frontiers Media SA, Switzerland
4	*Plant and Cell Physiology*	3.93	2.08	204–408	3000	12	Oxford University Press, England (Japan)
5	*Field Crops Research*	3.87	1.70	0	3550[B]	12	Elsevier, Netherlands
6	*Plant Science*	3.79	1.58	0	3000[B]	12	Elsevier, Ireland
7	*Environmental and Experimental Botany*	3.71	1.24	0	3000[B]	4	Pergamon-Elsevier Science Ltd, England
8	*Annals of Botany*	3.45	1.71	0	3564	12	Oxford University Press, England
9	*Plant Physiology and Biochemistry*	3.40	1.05	0	2740[B]	12	Elsevier-France, France
10	*Plant and Soil*	3.26	1.19	0	3860	12	Springer, Netherlands
11	*Plant Methods*	3.17	1.53	–	2490	Continuous	BMC, England
12	*Planta*	3.06	1.23	0	3860	12	Springer, USA (Germany)
13	*Physiologia Plantarum*	3.00	1.23	0	2250–3000	12	Wiley, USA (Denmark)
14	*Journal of Agronomy and Crop Science*	2.96	1.08	0	3600	6	Wiley, USA (Germany)
15	*Plant Growth Regulation*	2.47	0.90	0	3260	9	Springer, Netherlands
16	*Functional Plant Biology*	2.33	0.86	0	2700[B]	12	CSIRO Publishing, Australia
17	*AoB Plants*	2.27	1.10	-	1400	6	Oxford University Press, England
18	*Agronomy-Basel*	2.26	0.77	-	1635[C]	12	MDPI, Switzerland
19	*Crop Science*	1.64	0.86	0	1050	6	Wiley, USA
20	*Theoretical and Experimental Plant Physiology*	1.53	0.51	0	2750	3	Springer, Brazilian Society of Plant Physiology, Brazil
21	*Euphytica*	1.53	0.73	0	3260	18	Springer, Netherlands
22	*Crop and Pasture Science*	1.33	0.60	0	3000	12	CSIRO Publishing, Australia

[A]Values ($US) are for research articles or reports and do not include additional costs that may occur from taxes or publication costs, e.g. colour prints or figures, extra page numbers, reprints. Costs change and they are indicative as at the time of this publication (April 2020). Authors cannot be held responsible for any errors in costs; and readers are suggested to contact the journal website for accurate information on current costs. Many journals offer fee support and discounts for countries and authors not able to pay publishing fees – individual journals should be consulted for information.
[B]Gold Open Access (see individual journal website).
[C]Calculated from an article processing charge of 1600 Swiss Francs.

or number of years (e.g. in field-based agronomy studies) in order to meet criteria for publication.

The amount of data required for publication can differ drastically between journals, but typically follows the rule of diminishing yield increment. That is, for journals in the plant science area, moving from a journal with an impact factor of 2 to a journal with an impact factor of 3 may require one or two additional experiments that may take a couple of months. However, for top-tier journals the data required may take many more years of experimentation, and may require involvement of large and multi-disciplinary teams as well as a combination of many different methods in a single study. The latter is not always appropriate for a typical PhD project, in which case we recommend to 'publish as you go'. Leaving publications to the end of the project also comes with a danger that the key author takes a new position with a new project, and subsequently has no time or energy to write up the previous work. In some rapidly developing fields there is also a danger of losing the priority if the publication is delayed for too long.

Critical scientific thinking and accuracy of interpretation

Science differs from religion by the fact that nothing is taken for granted, and nothing is accepted without questioning. The Royal Society's motto 'Nullius in verba' translates to mean 'take nobody's word for it', and reflects the importance of accuracy in scientific research (Harmon and Gross 2007). The awareness of such factors and a self-critical approach to assure experimental accuracy is also part of the key characteristic of critical scientific thinking. Many papers are rejected as being too speculative. Young and inexperienced authors tend to make overstatements or interpret results without supporting experimental evidence.

The essential nature of critical scientific thinking is not limited to analysis or interpretation of one's own data, but rather, should be extended to the critical assessment of previously published data. Unfortunately, many authors have a tendency to cite the conclusions or statements made in other papers without looking at and checking the original datasets. In a worst-case scenario, the authors do not even bother to look at the original paper, but cite it based on a citation made by someone else. This results in a long chain of citations and potential spread of false or incorrect information. Critical scientific thinking could be encouraged in teaching at university undergraduate level, and exercises to test critical scientific thinking are given by Greenway *et al*. (2020).

Clarity, meaning and a writing style

A clear presentation will convey the meaning of experimental results to their best effect. Writers should think about their manuscript from a reader's perspective, asking, 'what does my reader need to know?' and 'how can I present this with the most impact?'. Images often have more impact than words, and simple graphs and figures often convey quantitative information better than tables. Graphics are also more likely to be remembered by readers. Readers may not read the full text, so the description of each figure should be complete: symbols should be explained and the key treatment described in each legend. The best writing style for a scientific paper is, 'precise, clear and brief' (Lindsay 2011). This type of language, often referred to as 'plain English', uses as few words as possible to explain the desired topic. Language should be direct, not round-about. This is another of the aspects that inexperienced authors tend to ignore.

Some authors write in what could be described as a 'me too' style (e.g. 'Smith and Jones (20XX) have reported . . . here it was also found that ...'). This passive voice or retiring style demonstrates a lack of confidence and also a dearth of both novelty and critical thinking, so should be avoided. Another frequent issue is inappropriate sentence construction. This may include statements such as, 'it is well known that' or sentences starting with 'Smith has reported . . .' or 'Jones has demonstrated . . .'. Our advice is to make your point, and then support it with two to three references.

Paragraph structure is also important. New issues warrant a new paragraph, usually consisting of three or more sentences. The first sentence should introduce the new issue and the last sentence should reinforce it. The first few words should contain the keywords for that paragraph. It then becomes possible for the reader to skim through a paper quickly, looking at just the start of each paragraph to see what is new and whether they want to read the details later. In this context, having informative subheadings with a one-sentence summary of the major findings reported and discussed in a section below is the best option to relay a message. When readers see long paragraphs or sections without subheadings that are several pages long they may lose the thread of the narrative and not read further. The authors have then lost the interest of the reader and are unable to explain and interpret their research.

Finally, scientific papers should not be written like a mystery novel, raising a question and then leaving the answer to the end. Rather, we suggest that the question and answer (or progress towards an answer) be raised at the start. Having a structure including informative subheadings is the best way of achieving this. Indeed, an informative title that clearly confers the main message of the work is often enough to attract attention and have the paper cited. Equally critical is an informative Abstract. It is always published for free and hence, may be enough for your work to be noticed even if the citing authors cannot get access to the full text.

Paying attention to details

One would be surprised to see how many papers are submitted without proper technical editing. Problems such as inappropriate indentations, misspelt words, incorrect capitalisation (especially in the list of references), missing italics or sub or superscripts, and inconsistent terminology are all common. These points may be seen as relatively minor, but they deliver a clear message about the authors' attitude to their work. It is especially frustrating to see untidy manuscripts for multi-authored papers. A messy submission sends a very clear signal to the editor or reviewer, suggesting that this is most likely a student's work, and the supervisors (often listed as co-authors) have not bothered to read it properly or provide constructive feedback. Thus, despite reporting some potentially interesting data, the chances for publication of such papers are slim from the outset.

References to published literature

Depending on the paper type (e.g. experimental vs review or opinion) and the journal, the number of references may vary between 10–15 and over 200. For a typical experimental research paper, 40–60 references are usually required. This is true for journals within the agriculture and plant biology field, and is also true for most other fields of scientific research (Heard 2016). Both the choice of cited papers and their quantity depend strongly on the authors' experience and personality. PhD students tend to cite every paper they have read while working on the project, whereas more mature academics are often 'guilty' of self-citation. The balance should be somewhere in between.

There is no clear consensus on whether the original research should always be cited, or if it would be better to simply refer to the latest review in the field. The latter seems to be the current trend, as many top review journals (with the highest impact factors) now require citations to be no older than 2–3 years. Regardless of the number or publication date (year) of citations used, the rule of thumb should be to show justice to previous work and clearly tell the reader about the current understanding of the topic and where the gaps are in the present knowledge base.

The style of the references is not critical, as long as it is internally consistent, and the journal's requirement for alphabetical or numbered listing is followed. However, the style must be internally consistent, and the data for year and volume number and other metrics should be manually checked, even when using EndNote or other citation programs, as some inaccuracies may persist.

Statistical analyses

With the complexity of research structure and data collection, both experimental design and statistical analyses are becoming increasingly important. Indeed, the repeatability of the experimental results is critically important. Professional statisticians or data analysts are now an integral part of many research projects and are needed for phenomics and other 'omics' research, as well as machine learning and massive datasets derived from the use of technologies with drones and satellite imaging. These experts are engaged at the start of the project, and they often take part in the writing of the manuscript. Journals attracting papers of this type may well have an expert statistician on the editorial board to provide advice to authors before the manuscript is submitted.

Even simple experiments involving a few treatments or genotypes in a controlled environment need to be analysed with a certain level of statistical expertise so that the most relevant and appropriate designs and analyses are used. File S1 (available as Supplementary material to this paper) describes the most up-to-date statistical methods for large-scale data-rich research projects, as well as for more confined experiments in plant science. File S1 highlights the concern of editors on the over-use of the *P*-value because it is 'too often misunderstood and misused in the broader research community' (Wasserstein and Lazar 2016).

Scientific journal survey

Editors-in-chief from 37 international journals in agriculture and plant biology were invited to participate in the survey, and 22 responded. Specific journals were targeted for this survey because of their range in (i) impact factors (IF, between 1.9 and 10.8) or Scimago journal rankings (SJR, between 0.6 and 4.7), (ii) country of publication, and (iii) scientific discipline within the general fields of agriculture and plant biology (Table 1). A total of 22 editors-in-chief responded to the survey request. The editors-in-chief from participating journals represent 17 different publishers from 12 different countries: Australia (2), Brazil (1), China (1), Denmark (1), England (4), France (1), Germany (2), Ireland (1), Japan (1), Netherlands (4), Switzerland (2) and USA (2) (Table 1). Most of these journals publish 6–12 issues per year (Table 1), and differ in their application of the Open Access model.

The majority of editors-in-chief who agreed to participate in the survey requested that individual information about the acceptance or rejection of manuscripts be kept anonymous, so the data presented here represent overall views of respondents. Survey information was collected using SurveyMonkey in October to December 2019. The overall mean percentage of manuscripts rejected by journals surveyed here is 71 ± 17%, with values ranging from 91 to 20% for different journals (Fig. 1).

The analysis of this survey has fully supported our view (as expressed above). The most critical features for acceptance of all papers are given as 'accuracy of interpretation', followed by 'critical scientific thinking' and 'importance of new findings' (Fig. 2). The 'clarity/meaning' of a manuscript was also clearly of great importance in determining acceptance rate (Fig. 2). Conversely, the reputation credentials of one or more of the listed authors is given as the lowest priority of the 11 characteristics listed (Fig. 2). The comments made by the editors-in-chief concerning reasons why a manuscript is accepted for publication are given in File S2. The findings highlight that the terms 'novel', 'novelty' and 'new' are the most important criterion for a successful manuscript, occurring in eight of 17 comments received. Further comments show that the scope of the journal, sound science, accuracy and clarity are also specifically mentioned as being important.

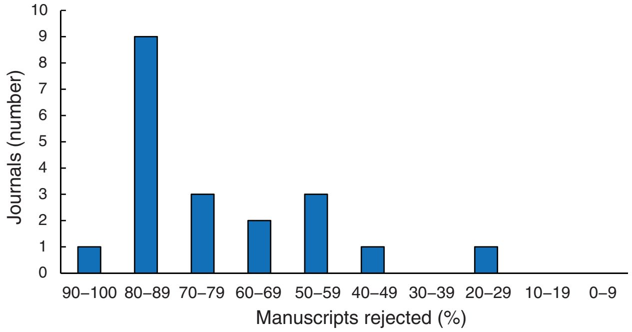

Fig. 1. Percentage of submitted manuscripts rejected for publication in agriculture and plant science journals. The overall mean of manuscripts rejected is 71 ± 17%. Twenty journals provided this information out of the 22 journals listed in Table 1 that participated in the survey.

The main reasons for manuscript rejection were the lack of novelty, issues with data interpretation, inadequate amount of presented data and its analysis, and poor critical scientific thinking (Fig. 3). The comments from the editors-in-chief about why a manuscript is rejected for publication are given in File S3. The comments highlight that often the reasons for manuscript rejection are not independent of each other. For example, clear and critical scientific thinking leads to clear writing. Hence, there is a 'syndrome' of poor papers, and there is a 'syndrome' of good papers.

The 'Write As You Go' (WAYG) model

The Australian Tax Office employs a Pay As You Go (PAYG) model to collect fees during the year, to spread the load and prevent the crashing shock of a one-off payment at the end of financial year. The same principle can also be applied to scientific writing. Commencing the writing after experiments are completed is highly inefficient, and it comes with the risk of losing the lead author to a different institution or country, and the ability to do follow up or additional experimentation. Ideally, key literature should be analysed and summarised *prior* to commencement of experiments, because no experimentation is possible without identifying current gaps in the knowledge. Using the 'Write As You Go' (WAYG) model suggests that after literature review and initial writing, experiments should be undertaken incrementally, with data analysed, figures drawn and a 'Results' section drafted after each specific milestone of a study.

One of the beauties of true academic research is its unpredictability. Very often, the end result may be inconsistent with the original idea, prompting a need for a major rewrite of the 'Introduction' when it is found that the draft version is no longer relevant or adequately focussed.

It is also crucial to understand that no paper should be a 'life-long project', and experiments should be stopped when enough data are collected. Realising when one must stop and when one should continue is not trivial, but can be learned through experience. The target journal also makes a critical

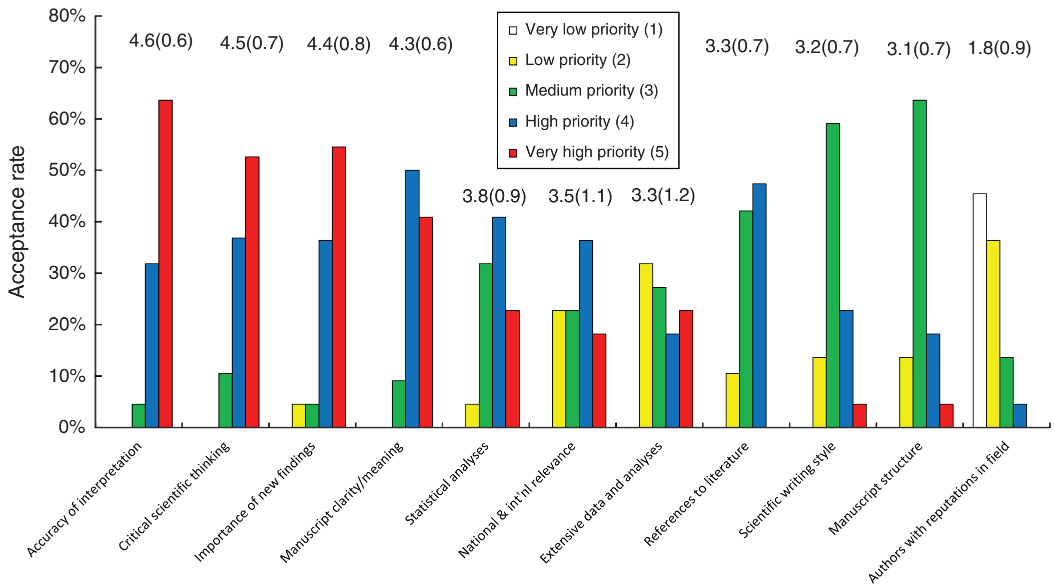

Fig. 2. The main reasons why a scientific manuscript is accepted for publication. Data from all 22 journals listed in Table 1. The mean (s.e.) for each characteristic is given above each histogram set by ranking very low, low, medium, high and very high as 1, 2, 3, 4 and 5 respectively.

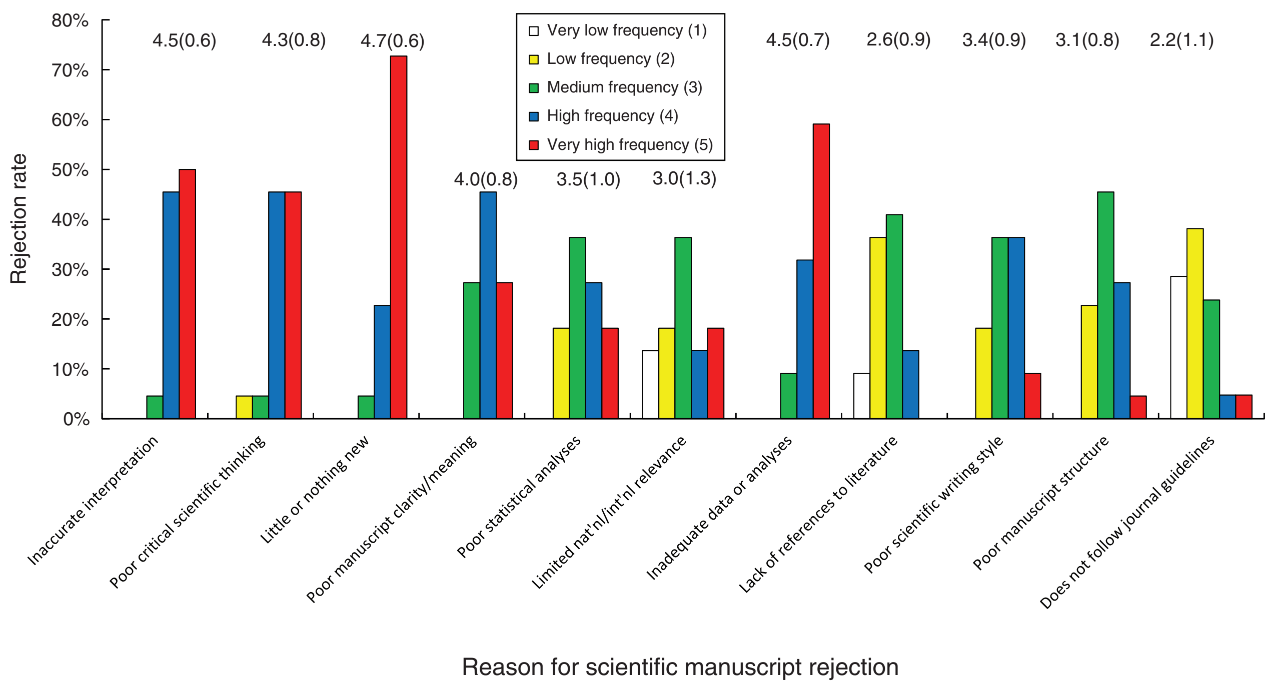

Fig. 3. Main reasons why a scientific manuscript is rejected for publication. Data for all 22 journals listed in Table 1. The mean (s.e.) for each characteristic is given above each histogram set, according to Fig. 2.

impact on this decision. From personal experience and after numerous discussions with our colleagues, we suggest that the most rational approach to help decide when to stop experimentation is to start writing the manuscript by presenting all available data. By doing this, it become easier to judge whether the story is substantial enough 'to be sold' or whether further experiments are required. Such an approach may also allow identification of possible omissions such as the need for additional controls and statistical measures. For these reasons, it can be seen that it is important to write in parallel with experimentation. The WAYG model also allows authors to take advantage of a

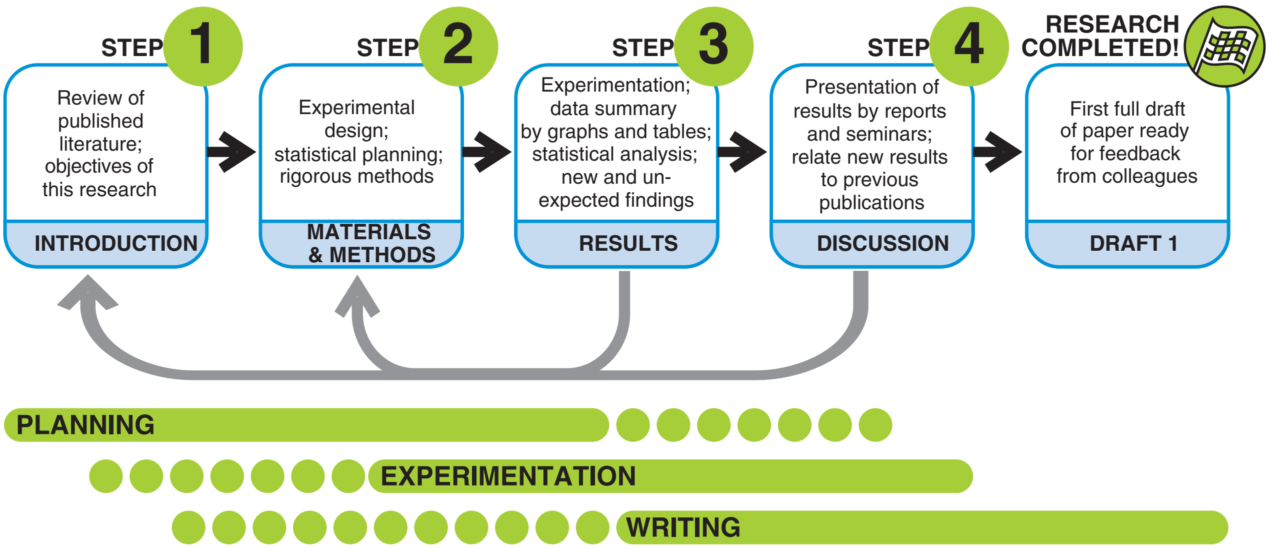

Fig. 4. Depiction of the progress of scientific research and publication. Writing can flow parallel to experimentation, and the four steps of experimentation become the four sections of the written paper. For post-graduate students the writing phase could start at Step 1, and for other researchers at Step 3. Expert advice on the scientific writing style, manuscript structure and 'writing behaviour' is given by Harmon and Gross (2007), Lindsay (2011), Gastel and Day (2016) and Heard (2016).

poster or oral presentation as an incentive to start writing a paper. The work done for the poster can be used simultaneously as the beginnings of a paper.

A schematic diagram of the flow of scientific research to publication is presented in Fig. 4, and this highlights the ideal relationships between the planning, experimentation and writing phases. Planning is the first phase that is primarily associated with a review of the published literature and the drafting of an 'Introduction'. Writing of the 'Materials and methods' should commence during the early stages of experimentation, ideally after the first experiment. Experimentation should then be punctuated by periods of review and discussion, resulting in cycles of further research and ultimately finalisation of the work (Fig. 4).

This repeated cycle of experiments, analyses, discussion and reporting enhances the critical analysis of the research. Colleagues can be asked to comment on the research plan before experiments are started. This could be an informal chat over morning coffee or more formally when the investigator feels the need for objective feedback. As well, the research should be punctuated by periods of review and discussion with future co-authors and colleagues to result in a cycle of further research and, ultimately, finalisation of the work (Fig. 4).

The final draft of a manuscript always benefits from feedback or comments from colleagues before submission. A friendly review before formal submission is an invaluable tool for improving the clarity and quality of writing (Heard 2016), as these 'private referees' are likely to point out any lack of clarity in text or figures, and where more explanation is needed for readers. For example, after the completion of early drafts, this particular paper was peer-reviewed by four private referees.

Concluding remarks

Starting to write a paper can be daunting, and it is easy to procrastinate. The 'Scientists Guide to Writing' by Heard (2016) contains useful, amusing descriptions of writing behaviour and the behavioural challenges experienced by new (and seasoned veteran) authors. Procrastination can be unintentional (e.g. 'I will start after lunch') or intentional (e.g. 'I don't have enough data yet'). Even after a manuscript has been started, it is easy to leave it unfinished and lying idle while jobs with apparent higher priority or urgency take over. The common reasons why a manuscript remains unfinished are distraction, interruption, lack of concentration, perfectionism or fear of criticism (Heard 2016). To maintain momentum and finish the manuscript an author must be disciplined and a set a self-imposed deadline. It is important that manuscripts do get completed and submitted because everyone needs to communicate their data, so the need to publishing work is real. Marathon runners are sometimes known to say, 'the pain is inevitable; suffering is optional', so it is with writing a manuscript. It is therefore up to the authors to make the writing and publication process as enjoyable as possible, knowing that the research is not complete until the paper is written and published.

Conflicts of interest

The authors declare no conflicts of interest.

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Supplementary Material: *Functional Plant Biology*

Supplementary Material

What makes a plant science manuscript successful for publication?

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File S1.

Presenting the experimental design and statistical analyses in scientific publications

A scientific paper should clearly present all statistical components in the entire experimental cycle, starting with the design of the experiment during the planning stage, going through the statistical model used in the analysis during the research stage and ultimately finishing with the predictions, based on the conducted analysis (see also Fig. 4). The description of the experimental design and the statistical methods used are usually given in the Materials and Methods section of a scientific paper. The results from the statistical analysis, including terms significance, observed patterns/trends and their interpretations are presented in the Results section. The R or other statistical package code used in the analysis may be presented in an Appendix, depending on the journal requirements.

In this paper we focus on planned and controlled experiments, and therefore on experimental design, typical for agricultural and biological experimentation. Sampling design and sampling strategies, typical for observational studies in e.g. ecology, marine and wildlife sciences, are not discussed.

Describing the experimental design.

Agricultural and plant science experimentation usually involve three types of environments: field, glasshouse and controlled environments. All of these are subjected to a spatial variability, e.g. moisture/fertility trends in the field, ventilation and exposure to light in the glasshouse and the controlled environment. Therefore, the most appropriate design for the above-mentioned environments should involve two-directional blocking, for example Latinised or Row-Column designs.

Irrespective of the experimental environment, the routine of designing an experiment involves the following steps:

(i) state the aims of the experiment and formulate the research hypothesis;
(ii) describe the treatment factors (e.g. nitrogen treatment, seeding rate, row spacing, genotypes) and their levels (e.g. nitrogen concentrations, number of genotypes);
(iii) select the response variables (e.g. yield, biomass) and determine the treatment structure;
(iv) decide upon an appropriate plot layout along with a description of the blocking structure;
(v) generate a randomisation of treatments to the experimental units.

It is important to describe the type of design that has been used e.g. randomised complete block design, row-column design, partially replicated design, etc. This should happen even before the research commences, during the planning stage of the research (Fig. 4). Details about the level of replication, the randomisation and the blocking should be provided. Often there are some practical restrictions related to the choice of blocking and replication, e.g. not enough seeds to allow full replication, issues with the soil homogeneity of the field, presence of strong neighbouring effect, presence of a slope, serpentine application of sowing/harvesting, spraying or other management practices etc. The latter should be clearly explained in order to justify the choice of the experimental design and later to be accounted for in the statistical analysis. The description of the experimental settings and design should provide sufficient detail to allow the experiment to be repeated.

Describing the statistical analysis.

In the same way that the experimental design is essential for allowing a researcher to repeat the experiment, the description of the statistical method should provide a researcher with an adequate understanding of the applied statistical techniques so that they can reproduce the analysis.

The treatment structure and the plot (blocking) structure are the two main components in formulating the statistical model. The treatment structure is selected to address the research hypothesis. For example, in the case of a factorial treatment structure one set of treatments (*factor*) is tested over one or more other sets of treatments. The plot structure describes the blocking or the replication, and in some cases e.g. split-plot design the plot structure also describes the nesting of the sub-plots within the main plots and the latter within the replicate.

It is essential for conducting the statistical analysis that both structures are included in the model. Linear mixed models (LMMs) and Generalised linear mixed models (GLMMs) should become the preferred techniques for the analysis of experimental data, including factorial experiments, common for plant and agricultural research (Welham *et al*. 2015; Schabenberger and Pierce 2001; Faraway 2016; West *et al.* 2014; Gbur *et al.* 2020).

The applied statistical methods and the relevant diagnostic checks, used to verify the assumptions of the statistical method, should be clearly stated. The two main components of the analysis, model selection and model checking, should also be presented and discussed (Gurka 2006; Müller *et al.* 2013).

Interpreting the results.

Current situation.

Most common experimentation involves factorial experiments, and for these experiments usually the significance of the model terms (factors and their interactions) is stated and discussed. The rule is first to describe the significance of the highest order interaction effect by presenting the probability levels with the corresponding F/Chi-sq statistics and degrees of freedom (df) along with some plots to determine what the interaction represents. If the highest order interaction effect is not significant, the consideration is given to significant lower order interaction effect(s) or main effect(s).

The statistical analysis is completed by presenting the predictions or estimates of the treatment effects/means of interest, based on the selected statistical model, along with some measures of their uncertainty. Tables or graphs of the treatment means are usually produced for the significant terms in the model, along with their standard errors (SE), confidence intervals (CIs) or standard errors of differences (SEDs). The means can be used to illustrate both, the specific differences of interest and, more importantly, to show the pattern of response to different treatment factors.

The above described routine is accepted by the journals but the manuscript and the study will benefit by wider exploration of the data, looking for some patterns and trends and different statistical approaches. Other issues related to misuse or misinterpretation of the results from the statistical analysis are described below.

Important issues to consider.

A review of recent published literature highlights that there are specific pitfalls to avoid, particularly in the interpretation of the results from statistical analysis.

(i) Avoid the automatic use of multiple comparison procedures.

Focussing on observed patterns and trends, or on a specific phenomenon typical for a particular subset of the data and warranting further investigation, is likely to prove more valuable than a simple comparison of treatment means using an ad-hoc multiple comparison procedure. Welham and Clarke

(2006) listed references covering research e.g. in the area of agriculture (Gates 1991; Pearce 1993), plant pathology (Madden 1982; Gilligan 1986) and entomology (Perry 1986; Bondari 1999), addressing the limitations of multiple comparison test. The latter provided numerous examples of cases where the naive use of different multiple comparison tests obscured the conclusions of experiments by producing contradictory results and undermining the validity of the conclusions. They warn that multiple comparison tests are often inappropriate in the analysis of experiments with a factorial treatment structure and that the interpretation of patterns in the significant main and/or interaction effects is more informative and offers better interpretation of the results.

The paper by O'Neill and Wetherill (1971) on multiple comparison methods included a discussion comment by J.A. Nelder "that data analysis is concerned with exposing patterns not with making a significance statement," and he did not favour the role of the multiple-comparison test in the interpretation of data.

(ii) Statistical significance and the misuse of *p*-value.
In the last few years a substantial number of publications (e.g. Nuzzo 2014; Goodman 2019) expressed concerns over the use of *p*-values to justify scientific claims. In response to this, the American Statistical Association (ASA) issued a statement (Wasserstein and Lazar 2016) discussing the concept of statistical significance and *p*-value. The *p*-value can be a useful statistical measure but is "too often misunderstood and misused in the broader research community". There were few issues discussed in the statement, which we consider as relevant and worth mentioning here.

Too much emphasis is put on the fact whether a *p*-value is greater or smaller than given threshold. Usually the studies are complex and there are other factors that may be affecting the result. The *p*-value or the statistical significance "does not measure the size of an effect or the importance of a result." This indicates that the presence of smaller or larger *p*-values does not necessarily specify the presence of more or less important effects or even no effect. Assuming precise measurements and a large sample can produce a small *p*-value; and in contrast, small sample size and poor measurement precision may lead to a high *p*-value. Also, identical estimated effects but with different precision will have different *p*-values. Hence, the *p*-value itself "does not provide a good measure of evidence" regarding the tested research hypothesis.

Some statisticians prefer to focus on different aspects in the analysis or even replace *p*-values with other approaches. Of particular interest is the focus on estimation rather than testing. The latter emphasizes the role of LMM/GLMM techniques in producing best linear unbiased predictors/estimates. Other approaches that offer alternative measures of evidence (e.g. likelihood ratios) may "rely on further assumptions, but at the same time more directly address the size of an effect (and its associated uncertainty) or whether the hypothesis is correct" (Wasserstein and Lazar 2016).

The increased complexity of the scientific research and experimentation, and the advances in statistical science itself, allowed the expansion of the applications of different statistical methodologies. It should be stressed that powerful techniques should be used with caution and be appropriate for the experiment and collected data. The selected model should also be carefully chosen, and the conducted analysis should allow proper interpretation of the statistical results. This is of greatest importance for the validity of the drawn conclusions.

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File S2.
Comments from Editors-in-Chief of agriculture and plant biology journals for key characteristics why a scientific manuscript is accepted for publication.

Each bullet point is from a different Editor-in-Chief.

- Answering a question or testing a novel and interesting hypothesis in the area is extremely important.
- Simply spoken: a clear hypothesis must be formulated and answered.
- Publish novel results and try to make a complete story so not publish fragmentary results.
- We discourage descriptive papers, and favour papers delving on cause-and-effect findings.
- Novelty and significance.
- As a method journal, accepted publications need to demonstrate a new, novel method or substantial improvements to existing methods.
- That the results represent some advance in the field of plant biology and are not simply confirming previous findings from another experimental system or approach.
- Significance of the finding and conclusions to the field. Novelty and breadth of application.
- Scientific novelty.
- High quality figures, good potential for citations.
- The science itself must be sound and appropriate for the questions asked.
- Read and align to the scope of the journal. Put the research in broader perspective if possible.
- Original data, provide novel insight.
- Novel ideas and findings of high importance in the field.
- Clarity of hypothesis/question and then relevance of the experimental design to test this.
- Accuracy. Poorly and inaccurately written manuscripts are quite disappointing. Of course the scientific quality is key, but accuracy is also important.
- Novel, substantial and making a difference to plant science.
- Reasons for why a manuscript is accepted for publication are difficult to generalise, since the journal publishes across disciplines and includes methodological as well as conceptual papers.
- The subject must squarely fall within the scope of the journal.

File S3.
Comments from Editors-in-Chief of agriculture and plant biology journals for key characteristics why a scientific manuscript is rejected for publication.

Each bullet point is from a different Editor-in-Chief.

- Descriptive studies with no relevance.
- Inadequate data analysis based on insufficient number of repetitions and experimental set up (one-time performance of trials).
- Normally the features of why a manuscript is rejected are not independent of each other; commonly poor papers have poor experimental design, unclear aims, poor structure, etc.
- English must be good. The method described must be new or demonstrate substantial improvement of an existing method. The importance of plagiarism.
- Studies that present large datasets (e.g. RNAseq) from a binary study (control v's treatment) have limited value. While they represent datasets that may be useful to the community, sending for peer review is actually wasted effort. Extensive time points or unique data could be compelling, but most of these binary large scale data submissions are desk rejected.
- Studies that employ a unique plant species will often sell this as a reason to be published, however the experimental work is derivative of work undertaken in multiple species over the previous decades e.g. measurements of stress markers during stress treatment. Authors need to better articulate why certain species or processes are being selected to study aspects of plant biology. Repeating work in another species needs to deliver some insight with regard to the species or the process being analysed.
- Not enough new important findings.
- Poor quality figures, limited potential for citations.
- Research too narrow to be of general interest. Inadequate analysis of the data.
- Lack of clear or rational conclusions.
- Poorly written; confirmatory results; insufficient data, e.g. only one mutant line; heterologous expression is insufficient.
- Inaccuracy.
- Too much work-in-progress or next-step.
- I wish they would actually read the scope of our journal, rather than tick the box that they have done so. It is a waste of their and my time.