Reporting Guidelines in Practice: A Good Idea, but Does Anyone Take any Notice?

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The pioneering work of members of NCR-101 in establishing and refining a set of Guidelines for reporting conditions for growing plants in controlled environments (CEs) is worthy of great praise (see the preceding two papers by Tibbitts and Krizek).

It was our observation however, that despite this unique and valued activity, plant scientists rarely reported the growing conditions of their plants in such a way that readers could make comparisons with their own experiments or independently repeat the published experiments.

With this in mind we set ourselves the following three objectives.

Objectives

- To determine and assess what authors do in reporting environmental parameters in CEs
- To determine and assess what the "Instructions to Authors" in journals actually instruct
- To appraise the current situation and propose future action

Our Objectives

What do authors do ? Our Methodology 1

1. *Select Journals - ISI data base "Journal Citation Reports"*
2. *Need 5 in each of 4 "regions/sets"*

- From USA
- From Europe
- From the East and South Pacific
- From the rest of the world

First Objective 1:

To find out what authors actually record in their papers to describe the growing conditions in their CE rooms and cabinets, we decided to survey a set of journals.

Our first criterion was that the journals should be reputable and esteemed and therefore we decided that they should be indexed in the ISI database "Journal Citation Reports".

Our second criterion was that we should cover the world-wide distribution of journals publishing papers in English. We divided the world into 4 regions or sets representing major publishing areas and sought five journals from each as being a manageable number to survey in the time available to us.

Our Methodology 2

3. Criteria for selection

- Subject = Plant Science (n = 139)
- Rank by Impact Factor
- Discard Review Journals
- Discard if not in Leeds University Library
- Discard if found to contain only a limited number of papers using CEs

The first criterion for selection of the 20 journals was that they should be in the JCR subject category of “Plant Science”. There were 139 of these in 1999.

We ranked them by their Impact Factors at the time.

We discarded Review Journals.

We discarded journals that were not taken by our University Library because we would not be able to inspect them.

We discarded journals found to contain only a limited number of papers using CEs to grow plants.

Title of Journal	Impact Factor	Society or Publisher
USA		
The Plant Cell	11.1	American Society Plant Physiologists
Plant Physiology	4.8	American Society Plant Physiologists
Molecular Plant-Microbe Interactions	3.4	American Phytopathological Society
Phytopathology	2.1	American Phytopathological Society
Journal of Phycology	1.8	Phycological Society of America Inc.
International Journal of Plant Sciences	1.1	University of Chicago Press
EUROPE		
Plant Journal	5.6	Society for Experimental Biology (UK)
Plant Molecular Biology	3.2	Kluwer Academic Publishers (The Netherlands)
Planta	3.2	Springer Verlag (Germany)
Plant, Cell and Environment	2.8	Blackwell Science Ltd. (UK)
Journal of Experimental Botany	2.3	Society for Experimental Biology (UK)
New Phytologist	2.1	New Phytological Trust (UK)
Photosynthesis Research	1.6	International Society of Photosynthesis Research (The Netherlands)
PACIFIC RIM		
Plant and Cell Physiology	2.3	Japanese Society Plant Physiologists (Japan)
Australian Journal of Plant Physiology	1.4	CSIRO Publications (Australia)
Australian Journal of Agricultural Research	0.9	CSIRO Publications (Australia)
Australian Journal of Botany	0.8	CSIRO Publications (Australia)
Soil Science & Plant Nutrition	0.5	Japanese Society of Soil Science & Plant Nutrition (Japan)
OTHERS		
Canadian Journal of Botany	0.8	National Research Council of Canada (Canada)
Canadian Journal of Plant Pathology	0.6	Canadian Phytopathological Society (Canada)
Israel Journal of Plant Science	0.5	Israeli Society of Plant Sciences (Israel)

Here is the set of journals that we considered, sorted by region and ranked within region by their Impact Factors and with their owner, whether it be a scientific society or a commercial publisher.

The “unshaded” journals are those that did not satisfy one or more of the criteria for selection.

We could not get five suitable journals in each of the “Pacific Rim” and “Others” regions so we combined the two into a single set of five called “Others”.

There are no horticultural journals in this set because their Impact Factors were too low.

The final set

USA	EUROPE	OTHERS
The Plant Cell	Planta	Plant and Cell Physiology
Plant Physiology	Plant, Cell and Environment	Australian Journal of Plant Physiology
Molecular Plant-Microbe Interactions	Journal of Experimental Botany	Soil Science & Plant Nutrition
Phytopathology	New Phytologist	Canadian Journal of Botany
International Journal of Plant Science	Photosynthesis Research	Canadian Journal of Plant Pathology

Here is the final selected set of fifteen journals.

Our Methodology 3

4. Accumulate 15 papers using CEs in each journal

5. Assign to one of three subject areas

- Growth / Development / Physiology
- Metabolism / Biochemistry / Molecular Biology
- Genetics

We then started with the first issue of 1998 and searched that year's issues for papers where controlled environments had been used to grow plants, until we had accumulated 15 papers in each journal. For the *Canadian Journal of Plant Pathology* and *Soil Science and Plant Nutrition* we had to go back to 1996 and 1995 respectively to get 15 papers.

We then assigned the papers into one of these three subject areas with the objective of comparing whether there were differences in the way in which scientists from different disciplines in plant science described the growing conditions of their plants.

Our Methodology 4

6. Tick yes if parameter is recorded as specified e.g. for radiation (5 fields)

- Units
- Average or Range
- +/- extremes
- Source of radiation
- Sensor of radiation

Each paper was analysed for each of the parameters in the 10 categories of the Guidelines (see the previous papers of Tibbitts and Krizek).

For each parameter a “Yes” was recorded if the author(s) reported the parameter as specified in the Guidelines.

For example for the parameter of “Radiation” there were these five properties or fields of the parameter. Each “Yes” scored one mark, so the maximum possible for “Radiation” was 5 marks.

The total possible mark varied between parameters e.g. air temperature and CO_2 concentration both only had the first three fields and therefore a maximum mark of 3.

Parameters of the Guidelines

Aerial parameters

1. Radiation.
2a. Temperature - air.
3. Atmospheric moisture.
4. Air velocity.
5. CO_2 concentration.

Edaphic Parameters

2b. Temperature - substrate.
6. Watering.
7a. Substrate - solid.
7b. Substrate - liquid.
8a. Nutrition - solid nutrients supplied e.g. fertiliser.
8b. Nutrition - liquid culture.
8c. Nutrition - solutions of nutrients added to solid substrates.
9. pH of the substrate.
10. Electrical conductivity of the substrate.

Guideline parameters.

Results - overall

Variate	Parameter		
	Radiation	**Solid Substrate**	**pH**
Geographic location (GL)	Significant (USA less)	Significant (Europe > Others > USA)	Significant (Europe > Others > USA)
Subject area (SA)	n.s.	n.s.	Significant (G/D/P only, other two zero)
GL x SA	n.s.	n.s.	Significant

The overall scores for each parameter were first compared between geographic location and between subject area.

The European papers scored highest or equal highest and US papers scored lowest, but only for three of the parameters - radiation, solid substrate and pH. Otherwise differences between geographical areas were not significant.

The subject area of the paper was not usually significant in affecting the score. For one parameter, substrate pH, “Growth, Development and Physiology” papers were the only group to report it, hence the significant result.

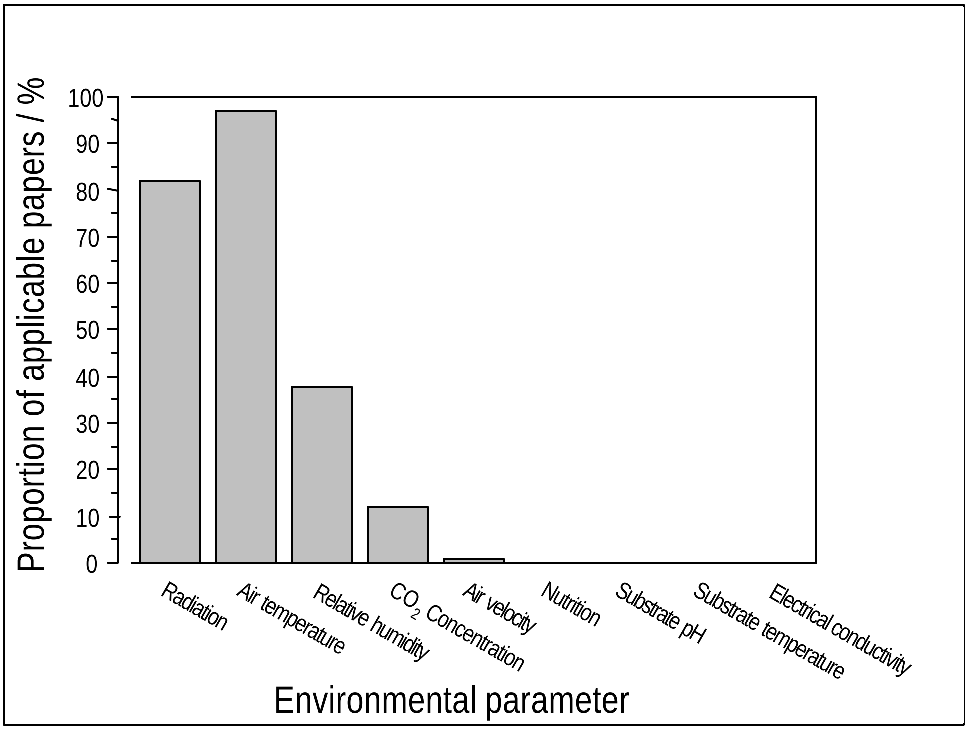
Results - specific 1

- Did a paper report a parameter at all?
- Comparing within and between the two sets of parameters - aerial and edaphic.

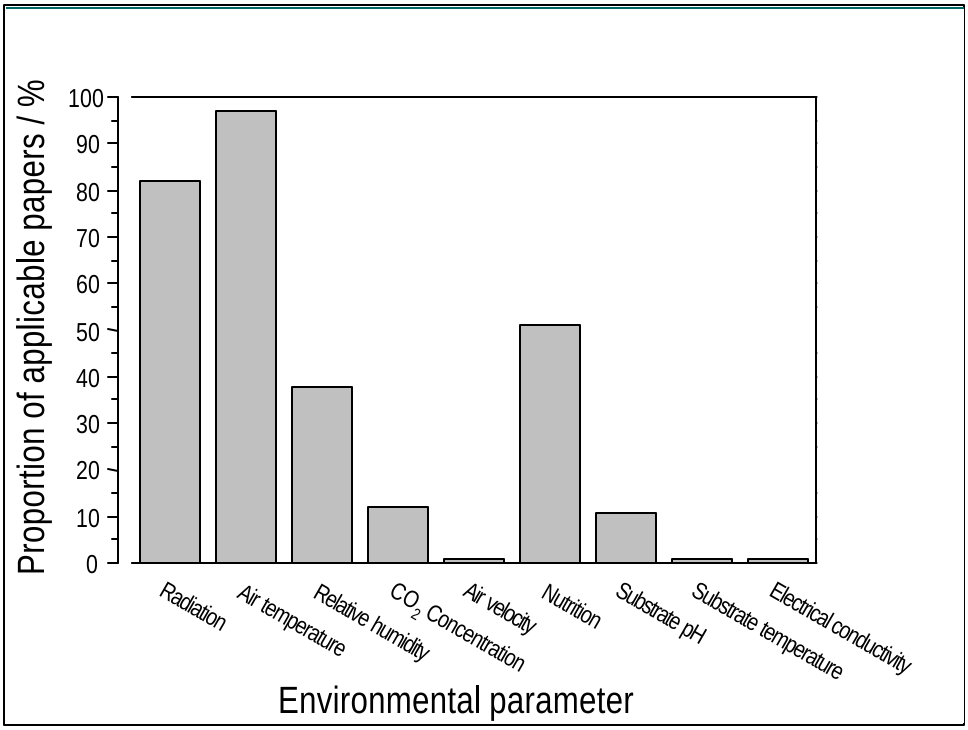
Then each parameter was examined in turn.

First of all did the paper report the parameter at all?

Secondly was there any difference in the quality of reporting of parameters within each set and between sets of aerial and edaphic parameters?



For the aerial parameters, "air temperature" was reported best of all but only "radiation" and "air temperature" were reported in more than 50% of the papers. "Atmospheric moisture" and "CO_2 concentration" were only reported in 38% and12% respectively and "air velocity" was rarely reported (1%).

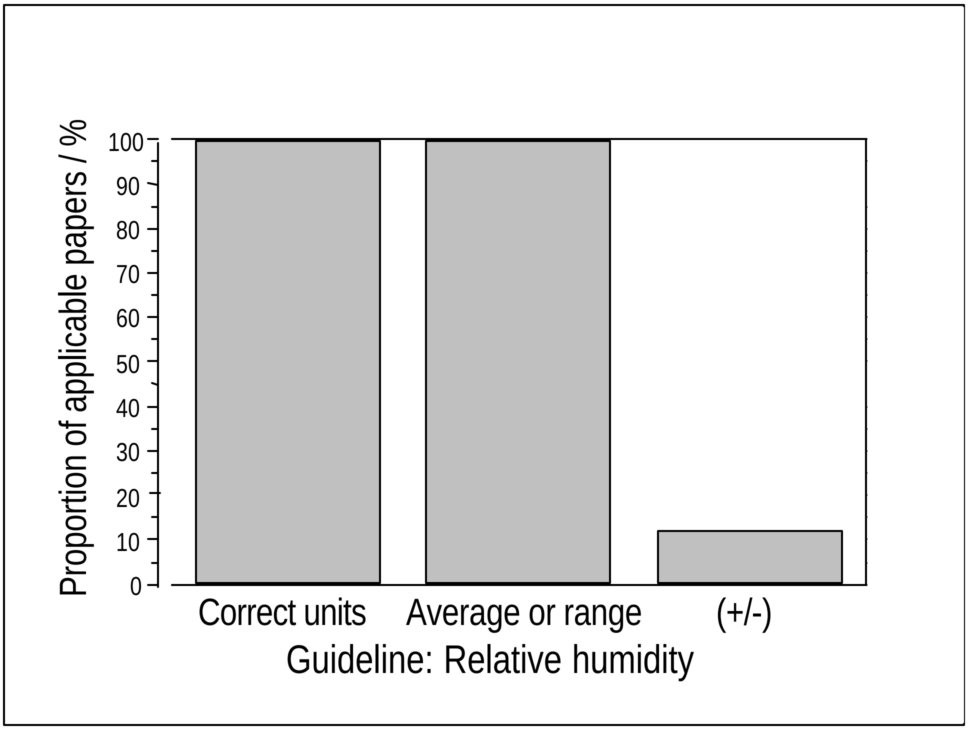


In comparison the edaphic parameters were poorly reported; only "plant nutrition" was reported with any frequency and then only in 51% of the papers. The other three were reported infrequently with "substrate temperature" and "electrical conductivity" rarely (both 1%).

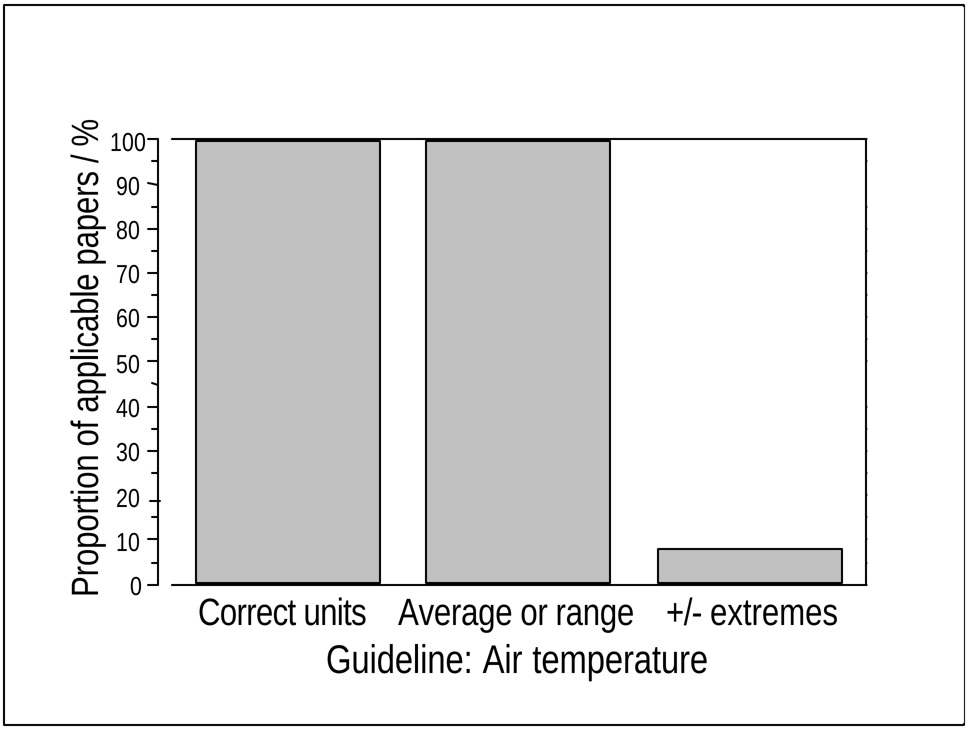
Results - specific 2

- How well did a paper report a parameter if it did so?
- Within individual parameters - we will now compare the reported properties - first for the ***aerial environment***

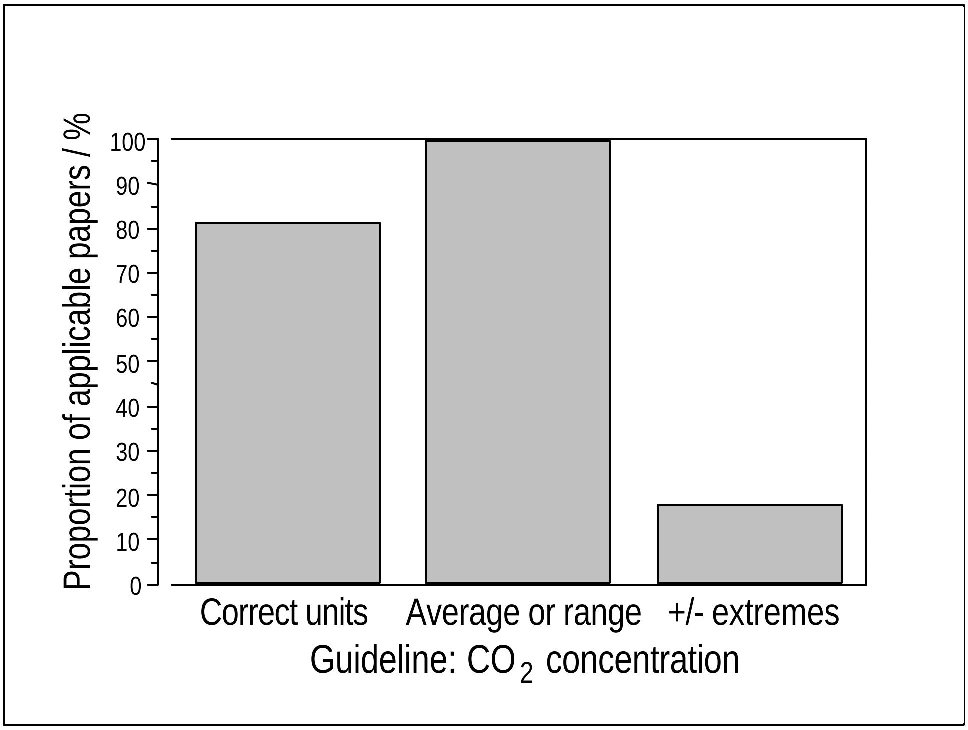
We then assessed how well each paper reported a parameter if it did so. We wanted to know what proportion of the papers that actually reported a parameter, reported each Guideline property of that parameter.



When authors reported atmospheric moisture or "relative humidity", they always used the correct units and specified a mean value or range. If they gave the mean value rather than range then they rarely (12%) specified limits either as extremes or standard deviations (or standard errors).

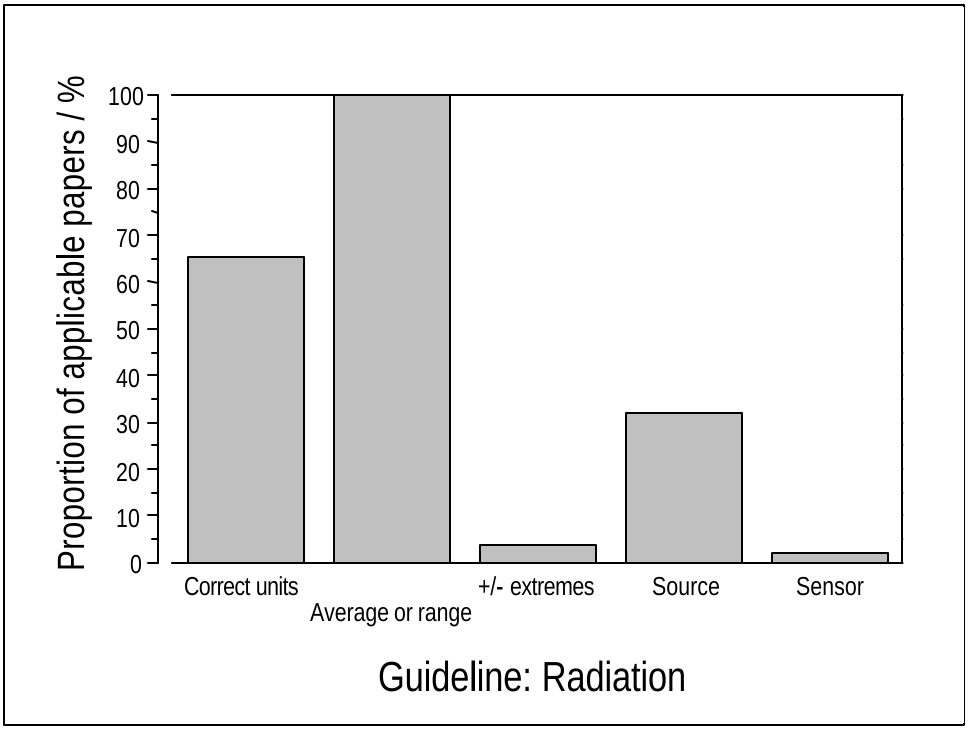


When authors reported “air temperature”, they always used the correct units and specified a mean value or range. If they gave the mean value rather than range then they rarely (8%) specified limits either as extremes or standard deviations (or standard errors).



For “CO_2 concentration” only 4 out of 5 authors (81.5%) who reported the parameter got the units right. The most likely error in units would be the unacceptable use of the non-unit, ppm. We are not allowed to use ‘mps’ for velocity (m s^{-1}) so why should ppm be acceptable? Besides ppm does not say anything about whether the proportion is by mass or volume.

Once again, if they reported the mean value rather than range, then they rarely (18%) specified limits either as extremes or standard deviations (or standard errors).



Even more authors, 1 in 3 (35%), failed to get the units of radiation correct. The erroneous use of micro-einsteins (μE) and lux was common.

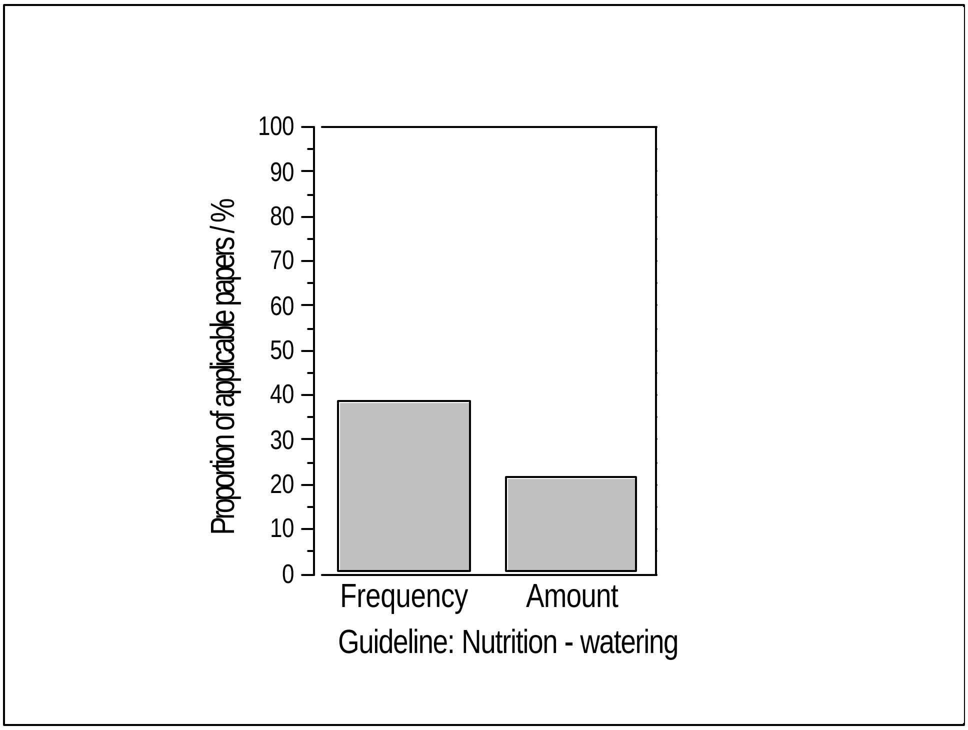
For those giving the mean value rather than range, only 4% (1 in 25 !) specified limits either as extremes or standard deviations (or standard errors).

Only 1 in 3 specified the source of radiation for their plants and only 2% named the type and make of sensor they used to measure radiation.

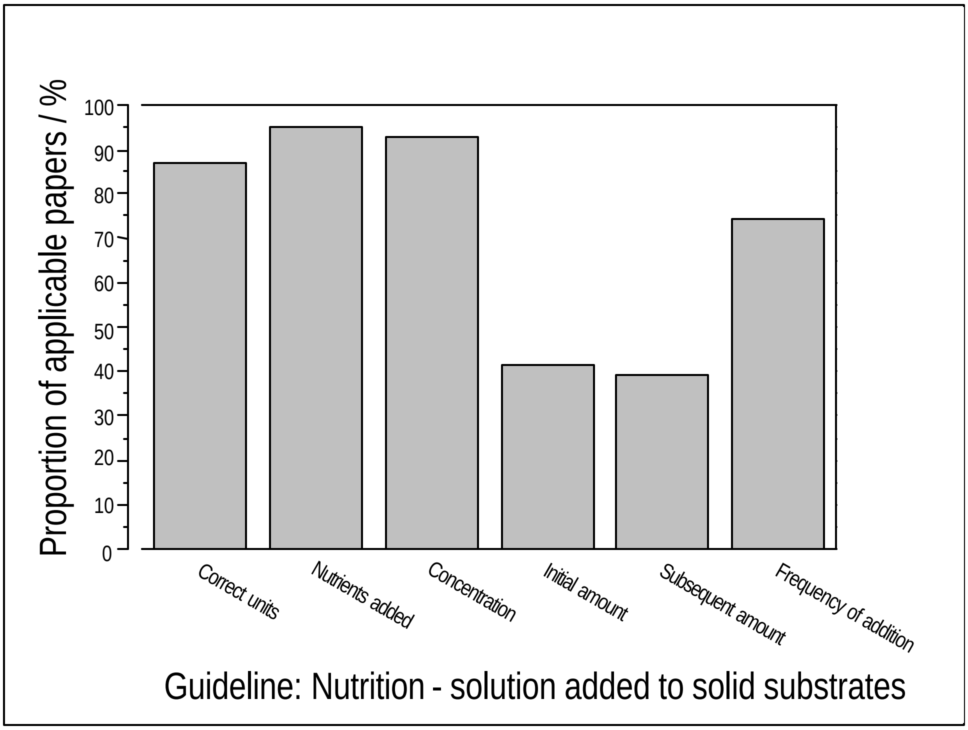
Results - specific

- Within individual parameters - we will again compare the reported properties - this time for the ***edaphic environment***

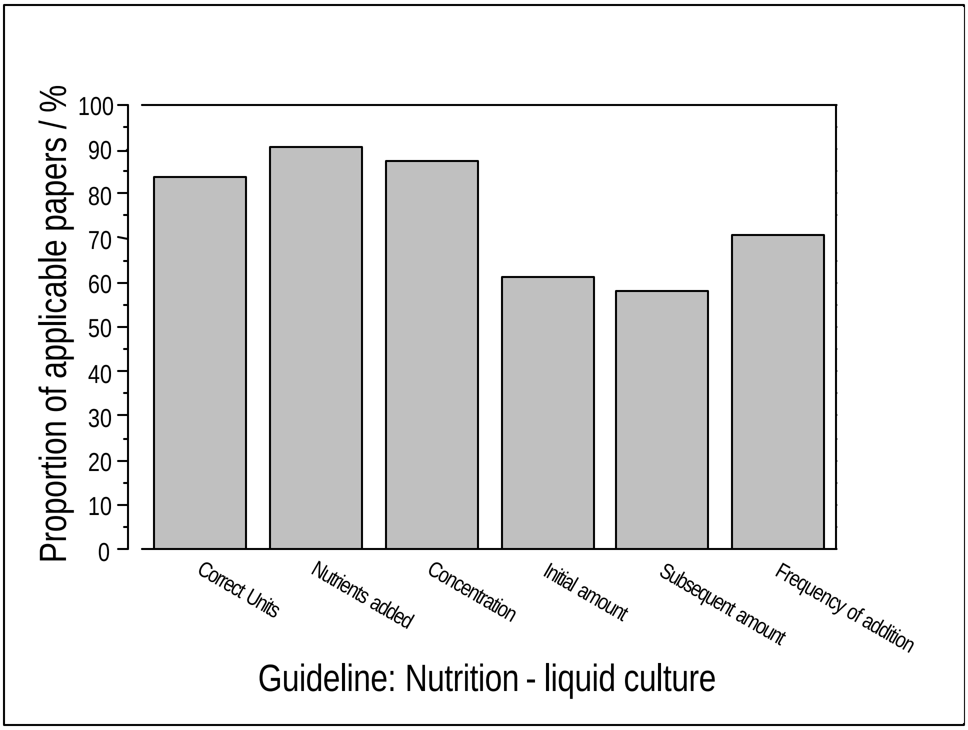
Edaphic Environment



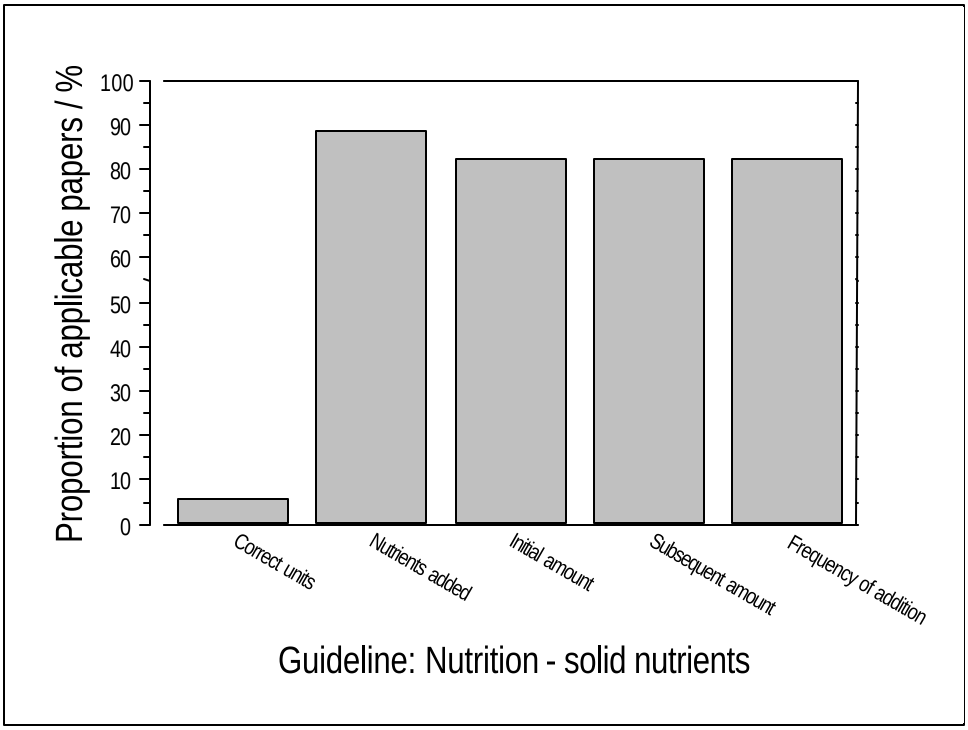
Of the papers reporting experiments that used solid media (other than agar) on which to grow plants (61%), only 39% of those specified the frequency of watering and 22% the amount of water added each time.



Of those papers (51%) which did describe their nutritional conditions, those that reported the details of additions of nutrient solution to solid substrates did so with varying completeness. Four of the properties were always described by 3 or more out of every 4 papers. Amounts of solution added were only reported by 40% of these authors.



Much the same applied to liquid culture, though in these papers amounts added were better described than in those where a solid substrate was used.



For papers where solid nutrients were added to solid substrates, the properties of the nutrient addition were described in 4 out of every 5 of the applicable papers. However only 6% got the units right. Concentrations were expressed in molarity which is not an accepted SI physical quantity for concentration, though concentrations in SI units can be derived from molarities.

Are the Guidelines referred to in “Instructions to Authors” ?

- Only ONCE - Plant Physiology refers to the CBE Style Manual which gives parameters and limits only
- NOT in ASHS journals
- NOT in the ASHS Style Manual

In reviewing these results, we wondered if, with evidence of often poor or no reporting, authors of papers in plant science knew about the Guidelines. Our second objective then was to determine and assess what the “Instructions to Authors” in journals actually instruct.

Of our set of 15 journals, only one, Plant Physiology, specifically referred to “the guidelines” and it referred authors to the CBE style manual (CBE = Council of Biology Editors) which gives parameters and limits only and cites Krizek *et al.* A wider survey revealed that the Guidelines were not referred to in ANY journal’s instructions to authors and most surprisingly not even in the journals of the American Society of Horticultural Science (ASHS). The ASHS was the ‘father’ of the Guidelines. Furthermore and astonishingly the Style Manual of the ASHS did not mention the Guidelines.

Instructions to authors

Title of Journal	Guidelines	SI Units	Methods	Subject area missing
USA				
The Plant Cell	NO	NO	✓	G/D/P
Plant Physiology	✓	✓		
Molecular Plant-Microbe Interactions	NO	NO		
Phytopathology	NO	NO		
International Journal of Plant Sciences	NO	NO	✓	Genetics
EUROPE				
Planta	NO	✓		
Plant, Cell and Environment	NO	✓	✓	Genetics
Journal of Experimental Botany	NO	✓		
New Phytologist	NO	✓		
Photosynthesis Research	NO	✓		Genetics
OTHERS				
Plant and Cell Physiology	NO	NO		
Australian Journal of Plant Physiology	NO	✓	✓	Genetics
Canadian Journal of Botany	NO	✓		Genetics
Canadian Journal of Plant Pathology	NO	✓		
Soil Science & Plant Nutrition	NO	✓		

Inspection of the instructions to authors showed that one third (5 out of 15) of the esteemed journals in our set did not recommend the use of SI units and conspicuously 4 out of the 5 were American journals. The luddite attitude in the USA to metric units, and thereby to SI, makes this result unsurprising.

Four of the 15 journals instructed that methods should be in sufficient detail that experiments could be repeated by others. This implies that conditions in which plants were grown should be given.

(The final column in this table indicates where a particular journal does not cover a particular subject area.)

Parameters - aerial - an evaluation

- Light - necessary but too complicated
- Photoperiod - completely missing!
- Temperature - necessary
- Water vapour - Saturation vapour pressure deficit (D_a) perhaps
- CO_2 - only if actually a variable
- Air velocity - no

Despite the apparent ignorance amongst authors of the existence of the Guidelines and of specific instructions for reporting conditions in CEs, nevertheless they did report some conditions, albeit in a less than satisfactory way.

In our opinion, many plant scientists nowadays have little knowledge of the importance of knowing values of physical variables of the environment in which they grow their plants or how to measure them. Indeed they simply use the CEs to generate sets of identical plants. They are usually not investigating effects of environmental conditions on their plants.

We therefore have examined the parameters in the Guidelines to assess their value and importance.

For the aerial parameters, we conclude that reporting radiation, photoperiod and air temperature is essential though the Guidelines make reporting of radiation unnecessarily complicated. We note that photoperiod is completely missing from the Guidelines.

It is unnecessary to report air velocity, CO_2 concentration and atmospheric moisture unless they are experimental variables. Indeed for the plant, the saturation vapour pressure deficit of the air (D_a) is the driving force for evaporation not relative humidity. Air velocity is usually determined by the manufacturer and cannot be varied.

Parameters - edaphic - an evaluation

- Watering - necessary
- Substrate - necessary
- Nutrition - necessary
- Substrate temperature - only if a variable
- Substrate pH - necessary
- Electrical conductivity - if a variable
- Aeration in liquid culture - missing

For the edaphic parameters, we propose that watering, substrate type, substrate pH and plant nutrition are necessary. In our opinion temperature and electrical conductivity of the substrate should only be reported if they are variables in experiments. We note that there is no mention in the Guidelines of the need to aerate liquid cultures. The uniformity and rate of aeration of liquid cultures should be reported.

We recommend that the Guidelines be revised to give a minimum and simplified set of aerial and edaphic parameters and their properties e.g. for light, where the photon content of the radiation is the most important property, one value of photon irradiance should be the minimum requirement. With this minimum set there could be a recommended minimum set of measuring instruments that a well-found plant science department or institute could be reasonably expected to own.

Substrate & Nutrition

- If *soil/sand/synthetic* - type, nutrients added (type, amount, frequency) pH, volume of container
- If *liquid* - aeration, nutrients added (as above), pH, frequency of complete change, volume of container
- If *agar* - type, volume or *f* of container

Here are the properties of the substrate and plant nutrition that we suggest should be reported. None of these properties require specialist knowledge or special measurement techniques to acquire.

The way forward?

- Via editors - not much hope - they are also the authors
- Via the authors - not much hope - we've seen the quality of reporting
- Via manufacturers of cabinets and instruments - educate
- Via engineers and managers of facilities - educate

We conclude that, regrettably, the Guidelines now seem to have little or no evident impact. There is a need to update them to account for changing circumstances.

Furthermore reporting in scientific papers of the physical and chemical conditions in the aerial and edaphic environments of plants growing in CEs, is not impressive. We believe that many of the current generation of plant scientists do not have the knowledge or the instruments to acquire and report values of physical and chemical parameters in their CEs.

In future the repository of knowledge about understanding and measuring environmental variables will reside with the manufacturers of CE cabinets and rooms and of measuring instruments and with the engineers and managers of facilities. The manufacturers must make an effort to stop using antique measures and units. If they have very good reasons to insist on using antique units like ppm then they should also give the SI equivalents on scales and as output variables from computerised recording systems. They should output the variables that users require as well as the ones that engineers require.

Finally groups like NCR-101 and UK CEUG should start running workshops for manufacturers, managers and engineers so that they can become the guardians of the essential knowledge and so that they can supply their users with useful data for publication.

Thanks to

- Don Krizek
- Our own teachers who thought that understanding physics, mathematics and chemistry mattered in biology