

Proceedings of the UK Controlled Environment Users' Group

2006 SCIENTIFIC MEETING

“QUALITY ASSURANCE – WHEN THE INSPECTOR CALLS”

Volume 17

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UK CONTROLLED ENVIRONMENT USERS' GROUP**2006 SCIENTIFIC MEETING****QUALITY ASSURANCE – WHEN THE INSPECTOR CALLS**

The scientific part of the annual meeting consisted of five invited contributions. Summaries of these, supplied by the speakers, follow.

SUMMARIES OF PAPERS

D. Glenister (Client Manager and Lead Auditor, SGS United Kingdom Limited, SGS House, 217-221 London Road, Camberley GU15 3EY, UK; E-mail: david.glenister@sgs.com) **QA from the inspector's viewpoint**

The SGS Group provides services in the field of Systems and Services Certification and Verification. Established in 1878 in Geneva, Switzerland, SGS now has offices and laboratories in more than 140 countries and is recognised as the global benchmark for the highest standards of expertise, quality and integrity.

ISO 9000:2000 is the international standard SGS are called on to assess more than any other. The standard evolved in response to the constantly changing global business landscape driven by technology and the ever-increasing customer demand for quality. Thousands of companies in over 100 countries have now adopted it.

ISO 9000:2000 is underpinned by 8 principles of quality management:

1. A customer focus.
2. The importance of leadership.
3. The involvement of people.
4. A process approach.
5. A systematic approach to management.
6. An emphasis on continual improvement.
7. A factual approach to decision making.
8. Mutually beneficial supplier relationships.

The benefits of certification are far-reaching. Certification to ISO 9000:2000 should boost an institute's, laboratory's or company's reputation, differentiate it from competitors and open the door to new markets. Customer confidence in a product or service should increase.

Internally, the standard should enable the institute, laboratory or company to continually improve its Quality Management System (QMS). It should reduce mistakes and costs, which over time impact on 'the bottom line'. Staff motivation should improve significantly as teams appreciate the value of the standard and welcome the need for constant improvement.

Support by regular SGS assessments should continue to improve the institute's, laboratory's or company's management system and processes. With a foundation of ISO 9000:2000 in

place, businesses can easily integrate other standards such as Health and Safety and Environment.

Applications in the controlled environment area

ISO 9000:2000 has many applications where the monitoring and analysis of the controlled physiological environment is of paramount concern.

Take “light” for example. Light needs to be consistent. Literally speaking, bulbs must not blow. This means designing a system to ensure all lights function properly at all times and at the right settings.

Prevention also requires a QMS in place, including an easily understood and implemented plan. It means developing a QMS that can be improved over time, for example by continually improving the detection system; thus increasing control over the local environment.

Certification to ISO 9000:2000 is a clear sign to staff and customers of commitment to continual improvement of an institute's, laboratory's or company's QMS.

The website at <http://www.uk.sgs.com> describes the work of SGS. This summary was taken from a full presentation, which can be found at <http://www.uk.sgs.com>.

G. Taylor (Weiss Gallenkamp Ltd, Units 37-38, The Technology Centre, Epinal Way, Loughborough LE11 3GE, UK; E-mail: garry.taylor@weiss-gallenkamp.com) **QA from the CE manufacturer's perspective**

The paper considers the role of the manufacturer in the implementation of Quality Assurance (QA) within the ‘Plant Science’ world and how its products can be included in an audit trail for experiments in controlled environments (CEs).

What does QA mean to a manufacturer?

The aim of a manufacturer is to deliver a product to its customer that is of a suitable ‘quality’-fit for the purpose of a particular customer or application. This requirement does not always demand the most sophisticated solution. It should ensure that the product:

1. Meets the published specification i.e. the product must be manufactured in such a way that it meets the specification that is declared by the manufacturer. After all, it is usually on the basis of some form of written performance that a product is selected.
2. Is safe to use i.e. designed and constructed in such a way that, when used correctly, presents no danger to either the user or the experimental material within the product. Some allowances also need to be made for a degree of ‘misuse’ that can be foreseen in the ‘real’ world.
3. Is reliable – as a part of a quality product, reliability is a major consideration of the design and is seen to be of utmost importance.
4. Is maintainable i.e. the product design should include elements that allow easy and minimal ways to maintaining the product. The ability to maintain the original performance specification is of primary importance.
5. Is profitable – in order to be successful in maintaining a healthy and innovative business, a manufacturer must be able to make not only product but also profit. Profit is also generally indicative of efficiency and ‘quality’.

Different manufacturers adopt a variety of methods of controlling quality within their organisation but most follow procedures that are implemented and monitor 'quality' during the manufacturing process, for example in the:

- **Design phase** by using proven standard product designs with known characteristics. Where novel products or projects are involved, established principles and experiences minimise risk to quality.
- **Development phase** when component selection is important, usually based on previous experiences. Requirement to comply with relevant manufacturing standards such as CE, EMC, machinery and pressure are all considered at this stage.
- **Manufacturing phase** where control of parts procurement and relevant supplier auditing are critical at the pre-production stage. Process and procedures documentation is a means of production control.
- **Testing phase** where the measurement of the resultant product takes place and it is measured against internal standards and product specification. Traceable calibration standards are essential at this stage.
- **Delivery phase** when in anticipation of the likely conditions experienced by the finished product during transportation to the customer, packaging and relevant shock tests are considered.

The ISO accreditation system is commonly adopted by some manufacturers as a method of controlling quality within its organisation. It should be noted however, that ISO 9001:2000 is only a method of control and monitoring of a manufacturing process, it is not necessarily a guarantee of 'quality'.

It is essentially a Quality Management System (QMS), consisting of:

- **Management's responsibility** for management with commitment to the principles, involvement.
- **Management of resources** - facilities, people, training and equipment.
- **Product realisation** with control over the processes - quotation, order, design, procurement, manufacture, delivery and service.
- **Measurement, analysis and improvement** to ensure that what the customer gets is correct, measure and check against specification - analyse and improve systems.

The ISO 9001:2000 standard ensures that, for the customer, the product is of consistent quality set against the manufacturer's own quality standard, that it meets the company's specification and relevant standards, that it passes all relevant safety standards and that the manufacturing processes are documented and performed in a quality manner. However, whatever a manufacturer uses as a quality standard it cannot guarantee 100% product performance at the customer's site.

How does a CE Manufacturer's quality standard fit into an auditable QA programme?

Can the product delivered directly from the manufacturer be included directly into the user's audit trail? Is it safe to assume that the installed equipment is exactly as it left the factory? Can it be assumed that no calibrated device drifted during transportation and that nothing moved, leaked or was damaged in storage or en-route?

Is it correct to trust that all the site services are perfect in their location, ambient conditions, water quality and pressure, and power supplies? In addition does the product meet the user

requirement specification (URS)? Were the user's requirements correctly conveyed to the supplier?

All the above factors are outside the control of the manufacturer.

With all these variables with potential to affect the performance of the equipment, how can the user substantiate a claim that an experiment was carried out under XYZ conditions? The question is, would the equipment withstand the scrutiny of an audit?

How well would 'Good Laboratory Practice' (GLP) be satisfied? Whilst no particular quality standards are associated with controlled environments, GLP might be considered as similar in its objectives. GLP is a laboratory quality standard generally used when assessing pharmaceuticals, agrochemical, cosmetics, food, novel foods and biocides. The GLP standard is also generally associated with hazards and risks to users, consumers, third parties and the environment and demands that studies are planned, performed, monitored, recorded, reported and archived. Results and data from studies carried out under GLP ensure that data submitted is a 'TRUE' reflection of studies and can be relied upon for risk / safety assessments. Is there not a similar requirement for some studies carried out in CE?

Unfortunately, controlled environments for plants, unlike many other pieces of laboratory equipment, are generally not considered as 'instruments' and are often subjected to a wide range of QA checks by the customer ranging from: -

1. 'Out of the box' approach - 'It does what it says on the tin';
2. Some form of untraceable measurements;
3. Methodical approach using calibrated instruments; to
4. Comprehensive manufacturer's installation and calibration tests witnessed by the user and signed-off.

Whilst the publication and distribution of the international 'Minimum Guidelines for Measuring and Reporting Environmental Parameters in Controlled Environments (2004)' has helped, many local practices still fall well below that 'minimum' level

Pharmaceutical CEs: An example of a highly regulated application of CE

Other industries using CE have a much more regulated approach to performance verification and yet have a similar requirement to study their 'product' under controlled conditions as do plant scientists. For example, the pharmaceutical industry uses CE to study the stability of a product with time and is interested in controlling temperature, humidity and light. The pharmaceutical industry regulator is generally considered to be the Food and Drug Administration (FDA), although other European and Japanese agencies are also involved, and it is very rigorous in its approach to auditing CE facilities. FDA audit inspections are routinely carried out on facilities and procedures, requiring strict measurement and record keeping of all controlled parameters, a process known as validation.

Validation

Validation is an on-site process carried out by qualified engineers, usually the manufacturer, to provide confirmation that a CE facility's controlled parameters comply with the product's specification/regulatory guidelines. The process uses measuring instruments that are traceable to national/international standards for values in line with manufacturer's designs and specification with results documented and archived i.e. supporting test data records to form a part of research project's audit trail. There are four protocols following FDA Guidelines viz.

Installation Qualification (IQ), Operational Qualification (OQ), and Performance Qualification (PQ) protocols. A manufacturer's standard data are not sufficient for validation!

What is a validation protocol?

It is a very detailed set of prescribed, structured tests to provide indisputable evidence that all factors affecting equipment function have been checked out by the manufacturer's validating engineer. The tests are not 'car service' tick box checklists! The validation documents are in structured 'test per page' format. Each test has:

1. Specific equipment details, an objective, a method, the acceptance criteria, (pass fail/limits), the results, comments, and corrective actions/non-conformances.
2. A sign-off - signature/date accepted by the validation engineer.
3. A sign-off - signature/date reviewed and accepted by the customer or a witness.

Validation provides documented PROOF to scientists, auditors, inspectors, regulatory bodies, and the safety inspectorate that the facilities are proven fit for purpose and comply with the experimental design.

What is in each protocol?

a) Installation Qualification (IQ)

This document verifies that the equipment is installed in a proper manner and in a suitable environment in which it is expected to operate. It consists of a positive signed proof that the individual components are undamaged, of the correct type, correctly fitted, adjusted and identified, and traceably calibrated.

Examples of CE room components would include: fans, motors, filters, heaters, cooling coils, wiring, humidifiers, lamps, communication cabling, instrument/measuring probe configuration, lamp type, and containment seals.

In addition, an IQ document would include positive, signed proof that the building utility supplies are correct, for example:

- Electricity - correct voltage, phase, fused, and contained, electrical safety tested, insulation tested, earthed and correctly identified
- Water - correct pressure, purity (conductivity), flow rate, filtered and drained
- Fresh air - correctly sourced, flow regulated, filtered and tempered

b) Operational Qualification (OQ)

This document contains positive signed proof of the phased start-up and running of the equipment after initial installation, for example:

- Controller and sensors system calibration
- Electrical motor and pump rotation, speed and current drain checks
- Air flow testing, velocity, volume flow and direction checks
- Cooling and heating system performance, currents and pressure checks
- Humidifier water levels, drainage and current checks
- Safety cut-out systems, operation, testing and calibration
- Lighting function, intensity and emergency lighting checks
- Noise measurements and power fail strategy checks
- Communication systems and condition alarm strategy checks
- BMS /SCADA/ PCs testing

c) Performance Qualification (PQ)

This document contains positive signed proof that the complete installed and operational systems are performing to specification in a real-life CE test situation.

Examples for CE rooms are:

- 24-hour testing of temperature, humidity and lighting (plus any other controlled parameter) at each of customers specified conditions - in a User Requirement Specification
- Tests to prove controlled conditions are unaffected by diurnal fluctuations in building services, voltages, water pressure, ambient conditions, room entry, plant loading, coil icing and defrost etc.
- Multi-point parameter logging arrays are used to capture conditions in extremities of the growing area in the room, to ensure consistent growing results
- Light mapping for level and uniformity



Figure 1. Example of a CE during OQ verification

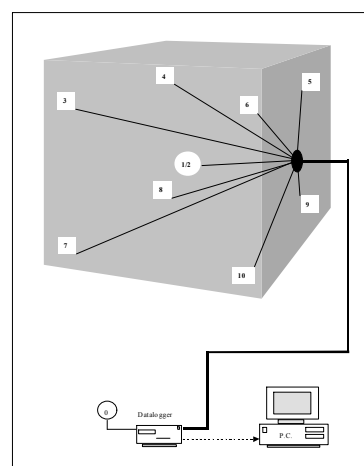


Figure 2. Typical data logging system

d) Performance verification (PV)

This process and documentation provides periodic re-confirmation that equipment is continuing to operate correctly and complies with performance specification /regulatory requirements with:

- Short form IQ, OQ and PQ testing
- Recording of 'as found' conditions
- Allowance for adjustments to original specification
- Allowance for considering historic data.

Data acquisition and archiving

It is vitally important to take and maintain accurate and indisputable records of environmental parameters for the duration of the experiment. From an auditing point of view ... "If it wasn't recorded, it didn't happen". Experimental records need to be accurate, reliable, trustworthy and secure.

Historically, real-time records were maintained using chart paper and ink, and this form of data capture was considered to be cheap, easy to read and values were difficult to falsify.

However, statistical analysis of data is not easy and archiving / recovery does not match the ease of electronic data capture.

Recently there has been a dramatic increase in the use of electronic data logging. Advantages include ease of use, can be networked, easy to archive, easy to analyse and graph, BUT data can be manipulated to remove 'undesirable' events. In recognition of this failing, the FDA has drawn up a set of guidelines that require electronic data to meet certain security criteria - 21CFR pt.11 compliance. Security aspects include encrypted data, electronic signatures, reports can be generated but records cannot be altered(!), which is consistent with the requirements of an audit trail.

The implications of validation for CE for plants

In view of the 'quality' of the science conducted in plant growth facilities and the need to record experimental parameters, is there a case for adopting a practice similar to the pharmaceutical industry? Aren't the same principles applicable?

When considering the need to audit a research project, which often requires equipment calibration to be confirmed, CE performance should be an integral part of a scientific audit trail. Unfortunately, all too often the cost of additional resources to carry out calibration / maintenance etc is considered to be too high. But what is the true value of a research project? If one considered all of the costs, including staff, building, administration etc, incurred in producing and analysing experimental plant material, surely the cost of validation of CE facilities is justifiable.

What about the future?

With the possible future development of phytopharmaceuticals, GM foodstuffs, novel foods and other plant biotech applications, one can expect more involvement of agencies like the FDA and therefore an increase in the requirement for validation of CE facilities. If this is the case, it is important that there is a common approach to the validation of measurement and recording of environmental conditions in CEs and maybe the 'International Minimum Guidelines' should be the basis of a validation protocol.

Issues to be considered are:

- Resources - need enough for suitable facilities that can withstand validation!
- Staffing for maintenance, measurement and recording - need sufficient numbers to carry out increased duties
- Training – need investment in qualified people
- Equipment testing, monitoring, archiving – need to purchase suitably modern monitoring instrumentation
- On-going funding - need enough to cover running costs and planned equipment replacement.

On a positive note, if the plant CE community adopts a 'pharmaceutical approach' to facility management, then this could raise the integrity of plant CE research, raise the importance of good facility management and endorse the importance of the leadership of the UK CEUG.

Summary

1. Buying a quality product is only a part of a QA programme.
2. *In-situ* validation is the only way of guaranteeing compliance with the user requirement specification.

3. Validation provides written PROOF to scientists, auditors, inspectors, regulatory bodies, safety inspectorate that the facilities are proven fit for purpose.
4. Validation provides documented evidence, which forms the basis for a qualified audit trail to be compiled.

References

International Committee for Controlled Environment Guidelines (2004) *Minimum Guidelines for measurement and reporting Environmental Parameters for Experiments on Plants in Growth Rooms and Chambers* <http://www.ceug.ac.uk>.

Code of Federal Regulations (21 CFR Part 11) <http://www.fda.gov/ora/compliance>

J. Franklin (Head of Horticultural and Controlled Environment Services, Technical Support Services Division, Rothamsted Research, West Common, Harpenden AL5 2JQ, UK; E-mail: julian.franklin@bbsrc.ac.uk) **QA from the CE manager's perspective**

Introduction

Over the last few years Quality Assurance has become an increasing part of a Controlled Environment Manager's work. The implications and implementation of Quality Assurance at Rothamsted Research are discussed as one example.

Why quality control?

Controlled environments are designed to grow plant material in defined repeatable conditions today, tomorrow and next year. Consequently we must be able to audit the process of repeating those conditions.

What is expected?

The need and breadth of any Quality Assurance is primarily defined by the customers, the scientists using the facility. The UK's Research Councils have published a joint code of practice which defines the Quality Assurance practices required from research funded by them. Sponsors of research such as DEFRA, PSD, DFID will also expect research to be conducted to defined standards. Within the publicly funded research institutes, Quality Assurance managers provide advice on the particular requirements of any quality assurance scheme but ultimately the immediate requirement is defined by the research scientists.

The Controlled Environment manager has to look at Quality Assurance in the following areas.

The experimenter's request

Most Controlled Environment facilities will have a hard copy- or computer-based request or booking scheme. Many also have data base systems for recording usage, for recharging, as well as details of the plants grown and treatments applied.

At Rothamsted Research we use a web-based request for space which ensures statistical vetting is applied, records both the permission of the line manager and CE manager, records any licence (Plant Health and Genetic Modification) requirements and records experimental details and operations into a searchable web-based database.

Environment

The parameters of the environment required for an experiment as defined by the user and the capabilities of the facility are set by the facility manager. These include:

Temperature	day/night thermoperiod differentials between heating and cooling deadbands on actuators ramping between changes in temperature
Light	level length of day/night integral shading light source
Humidity	day/night length deadbands on actuators ramping between changes in humidity type of control (% , vpd, water content)
CO ₂	day/night length of day/night
Watering	frequency amount quality of water
Uniformity	an indication of the uniformity of any of the above parameters should be given

The demands of the experiment determine what is required as do the capabilities of the facility providing the environment.

Records

Measurement of all that is set in the previous section should be kept at an appropriate frequency, and at an appropriate level of accuracy. The 'Minimum Guidelines for Measuring and Reporting Environmental parameters for experiments on Plants in Growth Rooms and Chambers' (2004) is a good starting place on what to report and on the location and frequency of measurements. Thought might have to be given to other environmental variables (such as absence perhaps of SO₂, NO₂ and ozone) but only if they are measured.

The security of any record is important and ideally backup copies of records should be kept. At Rothamsted Research electronic records are archived onto a backup server on an hourly basis. Longevity of the records is important and bespoke data formats should be avoided. This has been an issue at Rothamsted Research where older records have been in formats difficult to read with current versions of Excel for instance. In addition to the original request and environmental records, maintenance visits, repair records, alarm records, licences, and waste records should all be kept. At Rothamsted Research maintenance records and alarm records, including actions taken, are kept electronically and securely archived.

Resources used

The facility used should have been properly specified and there should be records of details of the facility, its fitness for purpose, operating instructions, as well as its supplier. A wide variety of growing media may be used and appropriate records of recipe, purchase, supplier date, and batch numbers should be kept. If an experiment is to be repeated, then sources and details, including dimensions, are needed of pots, labels, supporting materials, etc. The seed

source can be important as a seed dressing or growing history of the seed can affect the growth of any subsequent plant.

Having access to batch numbers for instance will allow a CE manger to pin down any problem with growing media. At Brooms Barn Research Station for instance knowledge of the batch numbers for a compost mixture identified an unfortunate inclusion of a pesticide which killed of aphids grown on plants with this mix.

The labour used, both the quantity, the number of man hours and quality (the individual) can affect an experiment. Who waters a crop, stakes and tends the plants? Identification of an individual may resolve problems or identify good practice. It may show up in inconsistencies between growth of sequential batches of plants.

Disposal of plants should be monitored to minimise wastage as well as ensure compliance with any licence requirement.

What is deliverable?

The magnitude and problems in delivering Quality Assurance at Rothamsted Research can be gauged from the numbers involved.

Experimenters' requests

At Rothamsted Research in 2004/5 there were 483 requests and in 2005/6 there were 508 requests for space or experiments in controlled environments and glasshouses. These varied from one pot for 4 weeks to 2,000 willow plants for 9 months.

Environment

Rothamsted Research has 175 CE rooms and cabinets, not counting other facilities such as tissue culture rooms and 176 glasshouse compartments of varying sophistication.

In the CE rooms and cabinets there are over 1,100 sensors and over 500 in the glasshouses. There are over 1,800 actuators in the CE rooms and cabinets and over 700 in the glasshouses.

Sensors and actuators are checked where possible annually. Accurate calibrations are performed as required, either to check a suspect sensor or for a specific experimental requirement.

Records

For monitoring purposes if we take 1,600 records (every sensor) every 5 minutes, 24 hours a day. In the course of a year 432,000 records will be generated. If it is assumed that there is 16 bits a record, over 10 Mb of disk space will be required per day. Data compression is operative at Rothamsted Research as well as event recording. Currently Rothamsted Research has 6 systems controlling and/or monitoring controlled environments or glasshouses.

Most records are kept electronically but the some have paper copies as well. Electronic records in some instances are updated from paper records.

Resources used

In the Rothamsted Research Controlled Environment facilities there 4.5 full time equivalent staff and in the glasshouses there are 5.5 full time equivalent staff.

Rothamsted Research uses annually over 20,000 pots and trays of 100 different sizes or type. Over 200 cubic metres of growing media are used, the majority specially formulated for work at Rothamsted Research.

Within the CE rooms and cabinets and glasshouses, 4 autoclaves, 2 ovens and 6 freezers are dedicated to the disposal of controlled waste. These are computer monitored to ensure that temperature regimes specified are complied with. The controlled waste is plant material requiring a licence to be grown and needing to be disposed of in a specific manner.

QA: If not, why not?

Implementing a Quality Assurance scheme costs money. A breakdown of the costs of implementing the measures taken so far to ensure that we meet the Quality Assurance requirements at Rothamsted Research is:

The cost of having Quality Assurance

The web-based experimental request system, based on a SQL database, took an estimated 625 man hours to develop. Assuming an average cost of £30 an hour the software cost £18,750. Maintenance and tweaking of the software takes around 60 hours a year.

There are over 1600 sensors and if annual calibration and checking were to take place, assuming a cost of £15 each, the cost for a team coming in and calibrating all our sensors on an annual basis would be £24,000.

On a similar basis, actuator checks at £20 each, assuming 2 checks a year, on average would cost £50,000.

To undertake calibrations of just humidity and temperature in-house would cost £11,000 for the calibration equipment and £1,000 for annual calibration against a reference standard.

To maintain records from the environmental control systems, current annual software and hardware maintenance costs are around £20,000. To maintain around a terabyte of information on the Rothamsted server network currently costs £100 for 5 years.

I currently estimate that at least one post, (a man year) is taken up with record keeping at a cost of £40,000 or around 10% of staff time in total.

The above costs exceed £134,000 or 9% of departmental budget or 0.9% of total institute spend.

The cost of not having Quality Assurance

In order to try and ascertain the costs of not adhering to good quality assurance standards we should look some 'typical' experiments and their costs:

Pesticides study Assuming a simple assay of 4 cages of plant material for 6 weeks. Plants would cost £250, 6 weeks of Insectary space £250, insect cultures £300, Junior Researcher's time for 1 week £2,000, i.e. £2,800 in total.

There are perhaps 20 to 30 such experiments each week and reproducibility is important.

Herbicides study Assuming a 1000-pot experiment for different herbicide tolerances for 3 months in a glasshouse. Glasshouse and plants will cost £7,200, 6

weeks of research time for analysis/harvest/treatments £12,000 i.e. £19,200 in total.

There are over 10 such experiments a year and reproducibility is important.

GM transformed seed. Assuming the use of 10 donor plants for 3 months grown in CE rooms at high light. Donor material will cost £1,800, research time to transform donor material plus facilities 12 weeks £24,000, grow plants to seed (6 plants for 5 months) £1,000 i.e. in total £26,800+.

Transformed plants number in 1,000s. Conditions for donor material are critical.

Arabidopsis analyses 1 seed tray for 10 weeks in Controlled Environment facilities will cost £4,000, researchers time for 2 weeks £4,000 i.e. £8,000 in total.

Over 1,000 plus trays each for a different analysis are grown every year. Many assays are linked assuming consistent conditions 365 days a year.

Rice studies An one-off study costs £81,000 in a Controlled Environment facility but the plants produce reference plant material that underpins research in Bangladesh, UK etc. and ancillary work costing £750,000.

The above costs demonstrate that plants grown in controlled environments are but part of the costs and that reproducibility, which quality assurance ensures, is essential. The total cost of running Controlled Environments at Rothamsted Research exceeds £1.8 million and the Institute budget exceeds £16 million. The loss or just the need to repeat a few of the above experiments will exceed the costs of Quality Assurance.

The message from sponsors is clear however: No QA, No money.

Final thoughts

Quality assurance is also concerned about the appropriateness of the requirement. Do I, as the Controlled Environment manager really understand what the researcher is asking for? Am I going to give the user what is required? For example in the production of seed, do I need really close control of temperature and does it matter if the conditions are precisely repeatable.

Research can be about the unexpected. Flexibility is important and documenting any response to a changing need or circumstance is important.

There is no point spending a lot of money on documentation or logging if no one looks at it including the Quality Assurance Audit team. It is important to liaise with the Quality Assurance team to provide what is required to meet the needs of the researcher, the QA Audit team and the sponsors of the research.

Acknowledgements

Ian Pearman, Laurence Benjamin and Rothamsted Research are thanked for discussion and their support respectively.

Reference

International Committee for Controlled Environment Guidelines (2004) *Minimum Guidelines for measurement and reporting Environmental Parameters for Experiments on Plants in Growth Rooms and Chambers*. <http://www.ceug.ac.uk>.

M. Long (Head of External Affairs, BSI Group, British Standards House, 389 Chiswick High Road, London W4 4AL, UK; E-mail: marcus.long@bsi-global.com) **Quality assurance from the standard setter's perspective – introducing standards**

Standards matter. They contribute at least £2.5bn each year to the UK economy and play a key role in enabling innovation, improving competitiveness, increasing reliability, ensuring safety, improving accessibility, controlling quality, managing risk and improving business performance.

As the world's first national standards body, BSI British Standards has a globally recognised reputation for independence, integrity and innovation. It is also a leading provider of standardization and consortia services through BSI Professional Services. Part of the BSI Group operating in 86 markets worldwide, British Standards serves the interests of a wide range of industry sectors, as well as government, consumers, employees and society overall to make sure not just British but European and international standards are useful, relevant and authoritative.

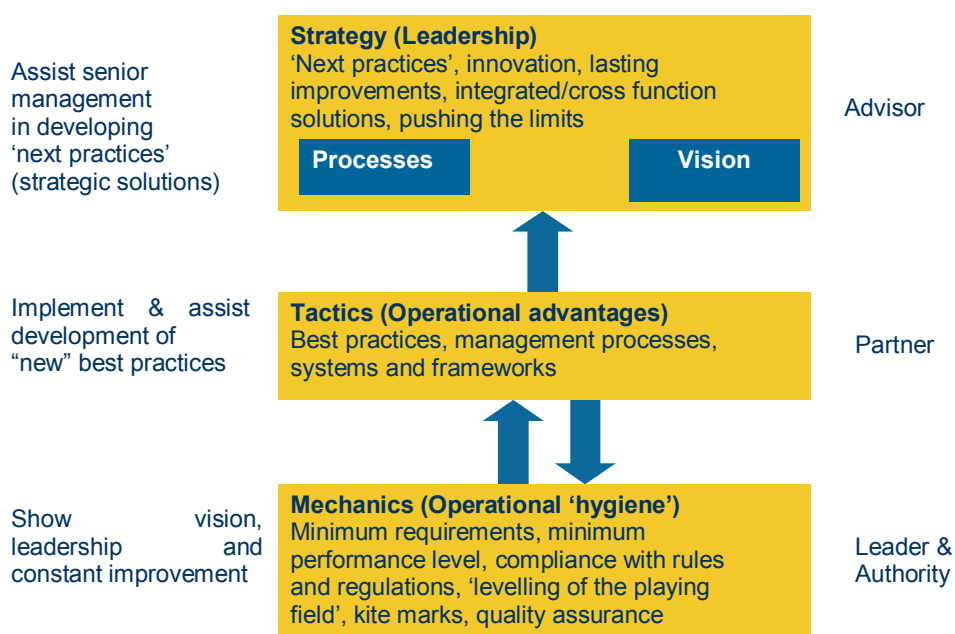


Figure 1. Role of British Standards in adding value

What is a standard?

A standard is a document defining best practice, established by consensus and approved by a recognized body (such as BSI). Each standard is kept current through a process of maintenance and review whereby it is updated, revised or withdrawn as necessary.

Standards are designed to set out clear and unambiguous provisions and performance objectives in order to help trade and communication but may also meet other needs. For example, they might improve the use of resources, assist with bringing products from development to market, stimulate innovation through the quick and efficient dissemination of

critical information, or improve the quality of life through health, safety and environmental requirements.

Although standards are voluntary and separate from legal and Regulatory systems, they can be used to support or complement legislation.

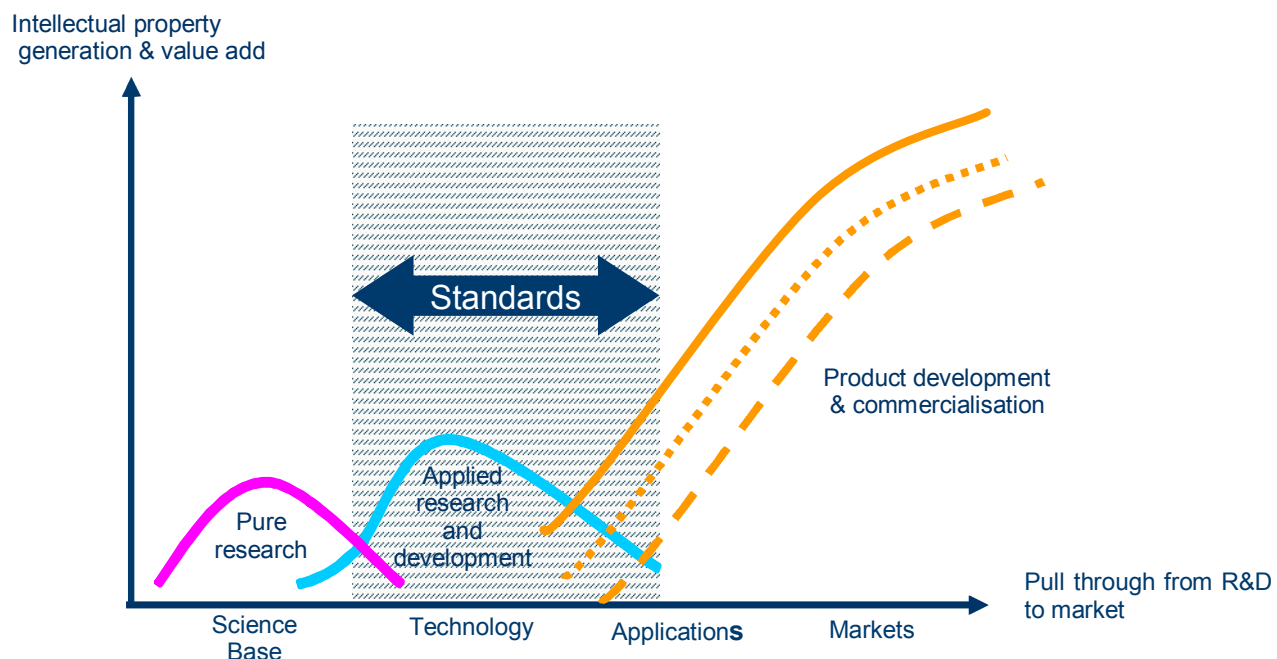


Figure 2. Role of standards in supporting technology

Some European Standards have been developed to support certain European (EU) directives by providing the simplest way of proving conformity. These standards in many cases are performance based rather than prescriptive. BSI manages UK interactions with the standards bodies for Europe: the European Committee for Standardization (CEN) and, through the British Electrotechnical Committee, the European Committee for Electrotechnical Standardization (CENELEC). Similarly, BSI is the British point of contact for the worldwide standards bodies: the International Organization for Standardization (ISO) and, through the British Electrotechnical Committee, the International Electrotechnical Commission (IEC).

The standards making process

Standards are developed when there is a defined market need through consultation with stakeholders and a rigorous development process. New areas for standardization are often developed through fast-track mechanisms like the publicly available specification (PAS) via BSI Professional Services. Formal standards in more mature areas are developed through a committee structure that operates at the national, European and international levels.

For fast track standards stakeholders are drawn together in a consortium model where consultation takes place through steering groups and review panels chosen to be representative and close to the business issues, and also through any standing committees in related areas.

For formal standards, national committees represent their communities in order to develop standards and related documents by consensus. They include representatives of government,

testing laboratories, suppliers, consumers, academic institutions, societal interests, business, manufacturers, regulators and trade unions. European and international committees represent the countries interested in the subject matter with the aim of reaching consensus, through expert delegations nominated by the relevant national standards bodies.

BSI supports almost 2,500 technical and subcommittees which between them have more than 22,500 places. BSI also provides the secretariat to over 200 European and international committees, and publishes 2,000 new or revised standards per annum as part of its current library of 27,000 standards. BSI Professional Services has set up over 40 fast-track standardization projects and published more than 90 PASs as the commissioned route to standardization has seen rapid growth in the last few years.

Types of standard

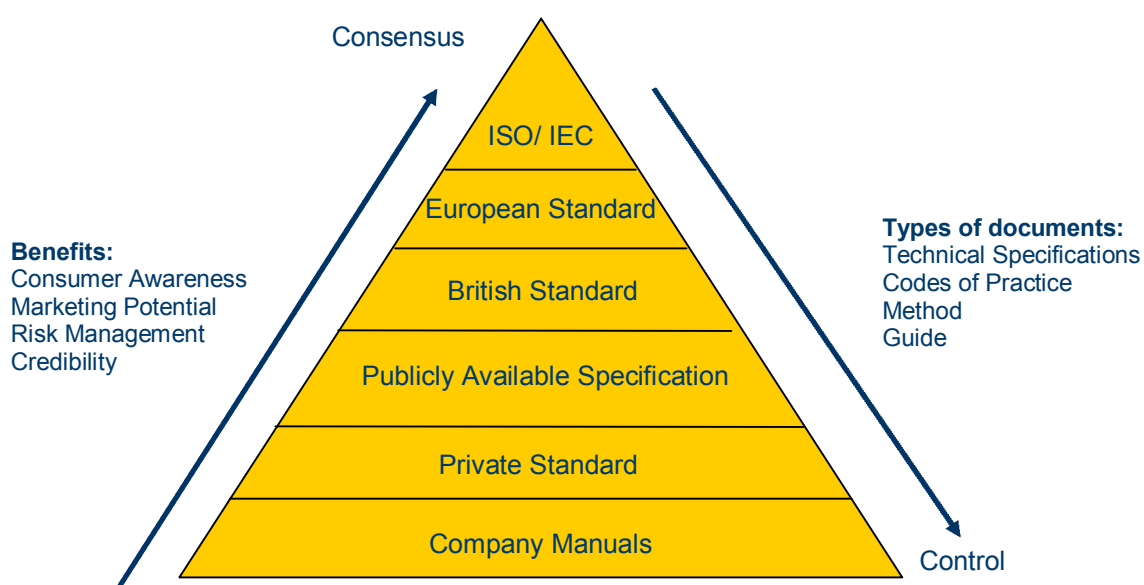


Figure 3. The standards control/consensus dynamic

Formal British (BS), European (EN) and international standards (ISO/IEC) are developed according to strict rules to ensure that they are transparent and fair. They follow the technical committee process which incorporates the following stages:

- Proposal for new work
- Project acceptance
- Drafting
- Public comment period
- Approval
- Publication.

There is, however, also a range of other documents with partial consensus:

- Draft for development - DD
- Guide — European Committee for Standardization CEN/CLC, or ISO
- Technical specification — CEN/CLC/TS, ISO or IEC/TS
- Technical report — CEN/CLC/TR, ISO or IEC/TR.

For some users of standards, particularly those in fast-changing technology sectors, it is often more important to agree on a business solution and publish it quickly before going through the checks and balances needed to become a full consensus standard. Therefore, BSI, CEN / CENELEC and ISO / IEC have developed a range of products which are not full standards but allow publication before full consensus. These publications are:

- Publicly available specification - PAS (the new deliverables of fast-track standardization)
- Private standard - PS (commissioned by specific organisations)
- international publicly available specification - ISO/PAS
- European or international workshop agreements - CWA/IWA/ITA
- business related books, CD-ROMs (e.g. Guides, Codes of Practice, compliance workbooks, text targets, surveys etc)
- Published document – PD.

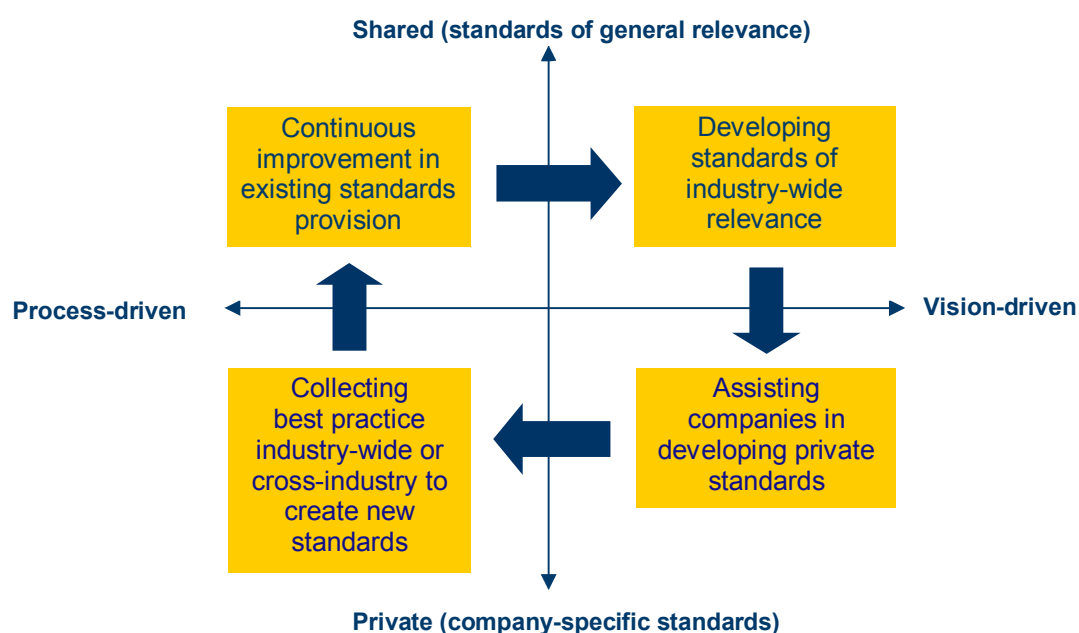


Figure 4. The standards cycle

Lead times for standards vary from a matter of months to several years. British Standards are usually developed within 12-15 months, whilst international standards take around 3 years. Commissioned standards such as PAS and PS can be developed within months to meet customer requirements.

Committees and consortia

British Standards facilitates the development of full consensus standards through committees representing interested parties. Committee membership is voluntary and DTI funding is available for some activities. Complementary to this BSI Professional Services facilitates a full range of collaborative and consortia services which are funded directly by participating organisations.

Committees develop national standards and provide the UK input to international projects. BSI staff, Programme Managers and Committee Managers provide defined levels of support

to the committees based on an agreed allocation of service that has been calculated according to the levels of importance and activity of the committee's current work programme. For national projects additional support is provided by editorial staff, Content Developers. Delegates and experts to international committees and working groups are nominated by national committees.

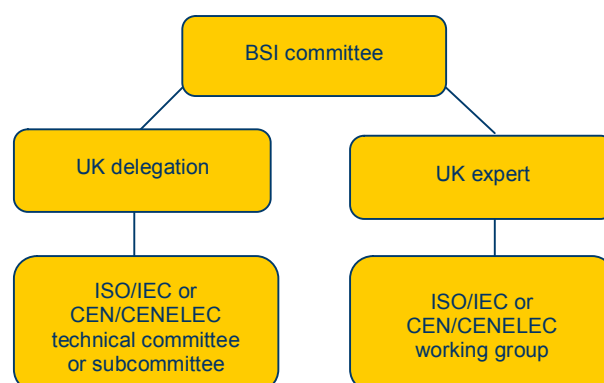


Figure 5. International representation

Consortia develop the fast track new deliverable like PASs as well as offering a full range of support services like post standardization marketing and PR.

There are state-of-the-art meeting facilities at BSI's Head office in Chiswick and committee interactions are facilitated by a modern electronic working environment 'eCommittees' that has been developed by BSI specifically for that purpose. All committees meet as often as required but the increase in electronic working means more standardization work is being done without meeting around a table. Consortia can be facilitated at BSI, client premises, or third party venues as required.

BSI committees usually include representatives from trade associations, academic institutions, government departments and other interested groups. Companies may nominate people to committees through their trade association.

If someone has a specific area of expertise, a committee may co-opt them for a specific task or an allotted time. A member of a UK committee may be nominated or appointed to attend international meetings either as a UK expert to a working group or as a national delegate to a technical committee or sub-committee. Similarly BSI consortia can commission expert input.

Benefits of participation

The development of standards requires specialist knowledge and a range of skills for which BSI provides world-class training. Although participation is voluntary and unpaid, committee members and experts benefit from helping to develop standards by:

- influencing the content of standards
- gaining detailed advance knowledge of standards and so anticipate requirements and trends
- getting to know peers and others who influence industry such as the business community, consumers, users, government and regulators

- winning recognition through association with leaders in the field and in media coverage promoting the standard
- being nominated for European or international committees.

Members of BSI fast-track standardization consortia derive key business benefits including:

- brand visibility and credibility by sponsorship of good practice
- strategic influence of standards in emerging new areas
- cost reduction, risk management, and product or service differentiation.

Further information

Several publications describe the benefits of using standardization to achieve broader organisational and national strategic objectives. Information about these is available both from BSI and the National Standardization Strategic Framework (NSSF <http://www.nssf.info>), a joint initiative between BSI, the Confederation of British Industry (CBI), the Department for Trade and Industry (DTI) and the United Kingdom Accreditation Service (UKAS).

The website at <http://www.bsi-global.com> describes the work of BSI and gives a range of information on British Standards.

The Standards Information Service, currently under trial, aims to provide a simplified method of those new to standards to understand what standards could be of use to their particular sector. <http://www.standardsinformation.com>

Projectline, the free service that enables anyone to search for British Standards currently under development, is at <http://webserv.bsi-global.com/projectline/>

L. Benjamin (Quality Assurance Advisor, Technical Support Services Division, Rothamsted Research, West Common, Harpenden, Herts, AL5 2JQ. E-mail: Laurence.benjamin@bbsrc.ac.uk). **Quality assurance from the auditor's point of view**

Why audit?

External audits may be imposed by regulatory or funding agencies. Internal audits should be part of a programme set by the Quality Manager as part of senior management's leadership of the organisation. The programme of audits should not be a fixed pre-defined timetable (for example Purchasing in January, Labs in February, Controlled Environments (CEs) in March etc.) but rather a schedule based on the priorities of management and on the status of processes. Hence, if changes in staff or equipment are planned, or have taken place, then an audit would be appropriate. An excellent reason for an audit is because it has been requested by the CE manager as part of quality control of planned or existing practices.

Role

The auditor's role is to assess whether the service provided by the CE facilities meets the requirements of its users. The requirements are diverse, including the need for the users to meet regulatory requirements, the standards sets by the funders for research and the organisation's own internal standards. It is not for the auditor to stipulate the standard that the auditee should be following. The auditor needs to gain this information from the auditee when preparing for the audit.

Standards

Unfortunately, there are no common, universally accepted CE standards for auditors to audit against. Sager *et al.* (2005) argued that the universally recognised ISO 9001:2000 standard for Quality Management Systems could be adapted for CE facilities. Their paper listed five tables, which specified the quality assurance measurements that should be made for radiation, temperature, atmospheric moisture, carbon dioxide concentration and air movement. For each environmental factor, they listed details of the sensor, alarms and calibration.

At approximately the same time, the International Committee for Controlled Environment Guidelines issued a 'Minimum guidelines for measuring and reporting environmental parameters for experiments on plants in growth rooms and chambers'. This set out a single table, which details the units, where and when to measure and what to report for radiation, temperature, atmospheric moisture, carbon dioxide, air velocity, watering, pH, electrical conductivity, substrate, nutrition and room or chamber properties.

These two documents do not have the authority of a specific standard, and it is unclear whether CE managers have the time or financial resources to make all the measurements stipulated in them. Furthermore they do not deal with the entire CE service.

A Joint Code of Practice for Research was written by the DEFRA, BBSRC, FSA and NERC which sets out the standards for conducting research funded by these four bodies. The section on equipment relates to CE facilities and states "where special facilities are used, they must be regularly checked and maintained. Equipment must be appropriate for measurements made, calibrated if necessary and in good working condition. If critical, there should be contingency plans in case of power failure or disruption." The difficulty with this deliberately non-prescriptive document is what is meant by 'calibrated if necessary'. For example, how is the CE manager expected to determine whether sensors for atmospheric moisture need calibrating? The dilemma is whether limited financial resources should be dissipated on calibration when the experiment's biological material is tolerant of a wide range of atmospheric moisture contents, especially given the apparatus in which these biological materials will be kept or the watering practices.

This highlights the need for CE managers to find out what environmental conditions are required by experimenters. One way of achieving this, is for experiment booking forms and/or on literature describing the facilities to explicitly set out the range over which each environmental condition will vary in each of the growth chambers available. These ranges should be set sufficiently wide to avoid demands to keep adherence to an impossibly demanding standard. The advantage of doing this is that it allows the researcher to consider whether the range of conditions is acceptable for his/her experiment. By documenting the responses from experimenters, the CE manager can build up evidence to present to senior management for the need for additional equipment for calibration (if such a need emerges).

The audit

An audit is not just an inspection of a set of 'things' (such as presence or absence of documents), but an investigation of a process. One widely-accepted approach to considering processes is based on the IDEFO model (<http://www.idef.com/idef0.html>, Fig. 1).

In addition to the core process of conducting experiments, there are the ancillary components of identifying Inputs, Resources, Outputs and Controls. In Fig. 1, a few examples are given

for each category. Arguably 'Outcome' is the most important category that needs to be addressed.

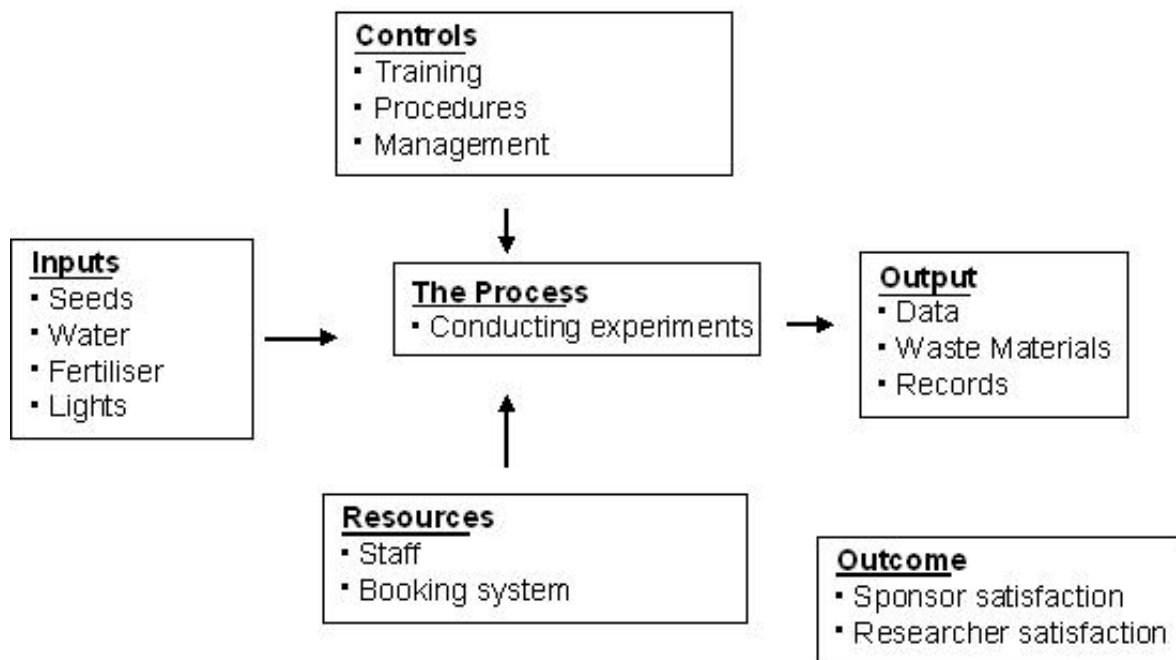


Figure 1. The IDEFO model for the process of conducting experiments in controlled environments.

The auditor will often request pre-audit meetings with CE staff to understand the process (hence the reason why the IDEFO diagram is useful) and to find out what standards and written procedures are already set out. When all this information has been obtained, the auditor can prepare a checklist of specific questions and arrange a mutually convenient date for the audit. The auditor's approach will be:

- To keep within the scope of the audit
- Impartial and objective
- To make no assumptions
- To audit against a standard and written procedures
- To look for evidence in the form of records, witness statements, certificates.
- To identify strengths and weaknesses
- To help to identify corrective actions

Auditors also need to be professional in their approach. Hence, they should not be passing judgement on the auditees, or gossiping about the audit.

After the audit interview, a report should be written, which should be vetted by the auditees for factual accuracy. The reports should be objective and quantifiable and will probably include observations and corrective actions. The report should identify strengths as well as any short comings.

A timetable for addressing the corrective actions should be agreed and a follow up audit should be planned.

Conclusions

- Auditing can be an important component of the quality control of the services provided by Controlled Environment services and should be a part of a Quality Assurance scheme.
- Auditors can be regarded as a resource available to the CE manager, and more use of them should be considered.
- For the Controlled Environment service to be auditable there is a need for standards to be defined and for there to be written procedures.
- Auditing is part of the process of continual improvement

References

International Committee on Controlled Environment Guidelines (2004) *Minimum guidelines for measuring and reporting environmental parameters for experiments on plants in growth rooms and chambers*. <http://www.ceug.ac.uk>.

International Standard EN ISO 9001:2000 *Quality Management Systems – Requirements*. To obtain a copy, go to http://www.bsi-global.com/Quality_management/Management/bseniso9001.xalter.

Sager, J.C., Norikane, J.H., Both, A.J. and Tibbitts, T.W. (2005) *Quality assurance for environment of plant growth facilities*. ASAE Paper No. 054137. St Joseph Mich., ASAE. 14 p. To obtain a copy go to <http://asae.frymulti.com/>, enter Paper No. and follow instructions.
