**RRES CONTROLLED ENVIRONMENT GROWTH CHAMBER SPECIFICATION B57**

**1.0 REQUIREMENTS**

1.1 The research conducted at Rothamsted Research (RRES) requires accurate and reproducible controlled environments for studies of arable and horticultural crops. These include plants such as wheat, barley, rice, oats, rye, tobacco, maize, soyabeans, sunflowers, cotton, lupins, lettuce, tomatoes, petunias, poplar, apples, and other selected experimental species such as Arabidopsis. These cabinets are required for research on plant stress and hence require good environmental control at the extremes of temperature and humidity.

 For the proposed research, accurate control of light intensity, far red/red ratio, day length, temperature, carbon dioxide level, relative humidity and airflow is needed. In addition, the environment must be free of excessive concentrations (above normal atmospheric) of undesirable gases such as ethylene, ozone, sulphur dioxide, and carbon monoxide as well as any trace phytotoxic vapours.

 For purposes of definition, the words "growth chamber" will mean the total system, and the words "growing area" will mean the area within the growth chamber where plants are grown. "Growth height" is the maximum distance between the light barrier or lamp bank and the floor or shelf on which the plants sit.

 A minimum of 4, separate, growth chambers to be located in B57 are required to meet the RRES requirement. To satisfy the research requirement of RRES, each controlled-environment chamber must meet the following performance and technical specifications. The price for four should be priced less items specifically requested to be costed.

 The supplier should supply details and addresses of at least three growth chamber installations, with at least one of a similar design, with permission to approach the present cabinet users.

 Suppliers must provide details of energy usage by these cabinets when they are using the maximum and minimum amount of energy, expected conditions being provided and assumptions for outside ambient conditions. In addition the energy usage at providing:

a/ 20°C, full light, 65% humidity with an outside ambient of 20°C 50% humidity, assuming 2 air changes an hour.

b/ -10°C, full light, (humidity irrelevant) with an outside ambient of 20°C 50% assuming 0.5 air changes an hour

 Delivery and invoice must occur before the 31st March 2017 with an expectation of an order being placed in mid-December 2016 at the latest.

**2.0 PHYSICAL CONSTRUCTION**

2.1 Materials

 Because the growth chamber is subjected to high humidities, it must be constructed of rustproof materials such as aluminium, stainless or coated steel, or plastic and all finishes must be non-phytotoxic. All materials used must be demonstrably non phytotoxic.

2.2 Size

 Due to constraints in the design of the building design cabinet exterior dimensions should be a maximum of 3.5 metres wide by 1.5 metres deep and 3.0 metres high. Internally growing height should be at least adjustable from 0.0 metre to 0.5 metres from the cabinet/platform floor to the ceiling of the cabinet (bottom of the lamp housing or lighting tray). Access to the growing area should be across at least 90% of the front growing area (width only).

 A growing area of at least 1.4 square metres is required. A growing height of at least 2 metres is required.

2.3 Interior and Exterior Finish

 The interior walls should be matt white providing uniform light reflectivity. Walls should be smooth with a minimal number of crevices or joints. Walls will be impervious to gases or water. The walls should be of such a nature that surfaces are easily cleaned and will last at least twenty years without discolouring, corroding or losing reflective ability. The exterior finish should be cleanable, easily maintained and not subject to corrosion, fading or discolouring after twenty years. Supplier will provide a list of materials suitable for cleaning the walls as well as a recommended cleaning schedule.

2.4 Insulation

 The chambers will be well insulated with a high overall thermal resistance. It should be noted the chambers could be running at -10°C and not ‘sweating’ or condensation should occur. In B57 the building temperatures are as a guide at 20 to 25°C with up to 70% humidity. The manufacturer will supply details of the thermal resistance of the chamber. Materials will be non-phytotoxic and resistant to decay or chemical breakdown, especially from water.

2.5 Floor

 Because the floor will be exposed to water, nutrient solutions (>pH 5), soil, and plant matter, it must be made of material that will not rust, corrode, or otherwise deteriorate under normal horticultural use. The floor should be easy to clean with no cracks or crevices other than a drain(s).

2.6 Doors and Seals

 Access to the growing area should be across at least 90% of the front growing area (width only). To allow for observation of the plants in the growing area without exposing them to the ambient atmosphere, the access door(s) must have a window of at least 100mm x 100mm in size that can be made light tight with a hinged cover. Door seals must provide a good seal. The supplier will supply details of how to replace the seals, with the appropriate source of the seals and current purchase costs. Door seals must be non-phytotoxic.

 Doors must be lockable.

2.7 Adjustable floor/ growing platform

 The growing floor platform must fit through the door opening and be easily removable from the cabinet for cleaning/replacement. The platform must be capable of taking a weight of 250kg square metre and must be adjustable in units of at least 10cm intervals from the floor. The lighting tray must be fixed and the growing platform adjustable from 0.5m to 1.5m from the lights. Height must be easily adjustable, in 10 cm intervals, but secured firmly when height not being adjusted. The platform surface must be easily cleanable and resistant to water and mildly acidic nutrient solutions.

 Cost of a spare floor/platform assembly is required.

2.8 Other Access Areas

 A minimum of one access hole must be provided to the growth cabinet for water, instrument leads and gas supplies. The hole must be at least 5 cm. in diameter, or equivalent area. The hole must be capable of being completely sealed against gas and light transfer.

2.9 Growth Cabinet Sealing

 The growth cabinet needs to be able to be sealed to allow high concentrations of gases eg CO2 to be maintained if required.

2.10 Services

 One double electrical sockets, are required, waterproof to IP 65, located outside the cabinet away from the door, placed 1.5 metres from the floor. Humidification will use Reverse Osmosis treated water (10-35 micro siemens). Costs of humidification in terms of parts required during a 5-year period and a maintenance schedule must be provided.

2.11 Filtration.

 Filters for the inlet fresh air should be accessible outside the cabinet. Filtration to exclude 200 micron particles or bigger should be fitted.

**3.0 ENVIRONMENTAL CONTROL**

 Temperature, humidity, airflow, and light must be controlled well enough to maintain the environment required for the research.

3.1 Temperature

 The required growth cabinet temperature range is -10oC to 45oC with no lights and -10oC to 45oC with all lights on. Chambers must be fitted with a suitable defrost to provide continuous use at -10°C lights on or off. Whilst defrost temperatures will rise these must be kept to a minimum with defrost management and the supplier must provide expected performance details. The maximum differential, as measured at the point of control should be less than +/- 1.0oC as measured with a shielded aspirated temperature sensor. The supplier will provide details of the accuracy and characteristics of the sensor used, NAMAS reference calibration certificate, as well as a calibration schedule.

 A uniformity requirement of +/- 0.5oC with respect to the control temperature, with or without the lamps on, across the growing area at the base is required. This will be measured with a shielded aspirated temperature sensor at 16 points in the cabinet.

 A maximum vertical temperature gradient of 1.5oC with respect to the control temperature from the floor to within 20 cm. of the lights is required with the lights on, as measured at eight points in the centre of each growing area. A uniformity requirement of +/- 1.0oC with lights off is required, from the base to within 20 cm. of the ceiling, as measured at eight points in the centre of each growing area. Temperature gradients will be measured with a shielded, aspirated temperature sensor.

 The supplier will provide documentation to support the temperature uniformity requirements for the temperature range -10oC to 45oC with lights on and off (where applicable) at intervals of 10oC.

 At a change in temperature from day to night to day, the above temperature uniformity must be achieved within thirty minutes. Separate day and night temperature control is required. The ability to ramp temperature at beginning and of day is required.

3.2 Humidity

Humidity control to maintain relative humidity in the range 40 to 85% +/- 5% is required with lights on and 40 to 95% with lights off. . A uniformity of +/- 5% humidity is required at eight point. A NAMAS certified sensor is required and a recommended recalibration schedule should be provided. The sensor should be easily accessible for recalibration but not requiring recalibration or maintenance at less than 3-month intervals. Documentation must be provided to support the humidity range specified. The humidity sensor should be in the same location as the temperature sensor. The dewpoints achievable must be below 4°C and be equal or greater than 35°C.

 Humidity stability must be achieved within 30 minutes of any control change, assuming a 20oC temperature change or 20% change in humidity.

Separate day and night humidity control is required.

3.3 Light

A light intensity of 1000 mol at 300mm from the lights is required, with a uniformity of ±10% at full 100% light, in the horizontal plane, over each growing area as measured at sixteen points. The lighting should provide a spectral quality close to natural daylight as possible using LED lighting. Valoya NS1 with a separate (controllable to adjust red far red ratio) far red is acceptable or similar. The supplier will supply the spectral quality ( including that of the far red source) of the lighting to be used as well as a sample for checking by RRES. Total lighting wattage must be indicated. Lighting should be capable of being reduced to give between 10 and 100% of the maximum output in stages, either manually or by a programmable control system with no loss of uniformity.

Far red lighting should provide at maximum 5% of maximum light level of the cabinet but must be separately dimmable and time clock controlled.

Lights must be separated from the growing area by a transparent screen.

Suppliers should specify options for different lighting types, fluorescent and metal halide with similar PAR output and cost of these different lighting types (if offered).

Light intensity in mol should be measured with a Skye quantum sensor or similiar in the 400 - 700 nm PAR region. Documentation of uniformity and absolute light levels at 50 cm. intervals from lights to the floor to be provided by supplier.

3.4 Carbon Dioxide

Positive Carbon Dioxide control is required, up to 2,000 ppm with control at +/- 20ppm. Carbon Dioxide is supplied from a central supply. Separate day night control is required. Documentation with details of the sensor used must be provided. The Carbon Dioxide will enter at a point where it will thoroughly mix with the conditioned air before being introduced to the growing area.

3.5 Airflow

Airflow of between 0.3 and 0.6 m s-1 is required to ensure good temperature uniformity. The airflow will vary no more than 10% from the average over a horizontal plane or vertical plane as measured in the centre of the growing area. Documentation with details of the sensor used must be provided.

The growth cabinet will also be equipped with an inlet to add fresh air from a ducted inlet if required. The ducted air will be prefiltered. However the cabinet will require a 200 micron filter on the inlet air accessible from outside the cabinet. The quantity of fresh air required will be adjustable from zero to four air changes per hour. The fresh air will enter at a point where it will thoroughly mix with the conditioned air before being introduced to the growing area.

Any air temperature and humidity measurements for the growth cabinet should be on the basis of two air changes an hour, with an incoming ambient of 25oC and 70% humidity.

**4.0 CONTROLS, MONITORING AND RECORDING**

Reliability of the control system is of utmost importance and it must be of high quality and proven design. At least three examples of control systems in use must be provided by the supplier with addresses and permission to approach the user.

4.1 A diurnal cycle (day-night) for temperature, humidity, CO2 and lighting (Incl. separate far red control), with each environmental variable independently settable is required

4.2 The controller(s) used will be capable of standalone operation independent of any external overseeing computer control and monitoring system. Any setpoints will be settable from the growth cabinet. Visible displays of current temperature, humidity, CO2, lighting (far red separate) and setpoints where applicable for these to be available on the front of the cabinet. In addition the status of the lights (% lights on, far red on) and CO2 valve will be displayed.

4.3 The system must be capable of resuming operation automatically on restoration of mains power after a break. Due to high switching loads etc. within a controlled environment building the controllers must be capable of withstanding anomalous power spikes etc. The controllers on each cabinet should have the capability of being programmed from a host computer to permit programming and operation from a central location. However, each cabinet controller(s) should have the necessary memory capacity to maintain control of the cabinet if the host computer is not operating.

4.4 The controllers should have a proven reliability record.

4.5 The controllers must be capable of being interfaced into a computer monitoring and control system. Such a system must be capable of altering setpoints on controllers, altering switching times, diurnal temperature, humidity and lighting, regimes. Ideally a front end SCADA type graphical package is required to ensure an optimal user interface. This should also provide data acquisition. Logging of environmental parameters, is required at a user settable rate, from once every ten seconds to once every ten minutes. Individual channels should be independently settable. Logging of temperatures should be in Microsoft Excel format with a graphical display available on an historical basis with up to one week at a view. The scales should be user adjustable giving the ability to zoom in on a particular set of data. Access to the logged data both in terms of a graphical display and logged data should be via a graphical SCADA type interface. The software should record and log all alarms notifying the user as these occur via e-mail and on screen display. Any alarm should only be resettable by an authorised person. This SCADA package must be priced separately.

4.6 An energy monitor monitoring electrical consumption to be installed on the cabinet preferably logged.

4.7 The supplier will provide details of the accuracy of the systems used and the cost of spare controllers.

4.8 Full documentation and user training of software will be provided. The cost of a spare controller should be priced separately. The cost of training should be priced separately.

4.9 All software must be capable of interfacing over the RRES Intranet with various RRES users.

**5.0 ALARM SYSTEMS AND OTHER EQUIPMENT**

 Each growth cabinet control panel should have a visual and audible alarm that is triggered by the high and/or low limit control(s) if their temperature, humidity or lighting settings are violated. A set of "volt free" contacts is required for connection to a remote alarm system, energised by an electrical system separate from that of the growth cabinet(s). Ideally, an alarm system attached to a modem that will automatically dial and alert an engineer would be preferred.

5.1 Other Equipment

 The controls, relays, or solid-state components, such as circuit boards and circuit breakers, must be easily accessible for service.

5.2 The design of LED lighting racks may admit conditioned ambient air for cooling. If user settable temperature limits are exceeded in the growing area the lighting must be switched off.

5.3 A volt free contact to link into the Rothamsted BMS is also required.

**6.0 OPERATING CONDITIONS**

 The growth cabinets will be housed in an air conditioned building where the temperature will be 20°C ±5°C. Humidity’s would be in the usual UK ranges.

**7.0 INSTALLATION**

 Installation will be by the growth cabinet manufacturer. An agreed plan for services and base layout will be provided. A timetable of works, including commissioning will be agreed prior to work commencing. Installation should be completed by March 2017.

7.1 All instructions and manuals including 2 copies of each will be provided to cover the operation of the cabinets. A list of spares that should be held at RRES with costs must be supplied. The supplier will provide a cost for training a Rothamsted service engineer and one other on the supplier’s equipment. A cost for maintenance over a five-year period assuming a 24-hour call out is required.

**8.0 REFRIGERATION SYSTEM**

 An integral water cooled refrigeration supply for the cabinets is required. RREs will provide a supply of water at 5°C +/- 3°C. Supply and volume of water to be determined.

 A CFC free refrigerant with a GWP of less than 2500 must be used. The supplier must specify the refrigerant to be used.

**9.0 STANDARD OF PERFORMANCE AND ACCEPTANCE OF EQUIPMENT**

 The specifications as laid out above, will constitute the performance specifications to be met. Acceptance will only be made when testing performed by the supplier has been accepted by RRES staff, which will be within a month of completion of installation by the supplier. If the performance specification has not been met, the appropriate modifications or repairs will be made by the supplier and any tests required accepted by RRES staff.

**10.0 TESTS DURING ACCEPTANCE PERIOD**

 When the equipment is installed the minimum tests required to gain acceptance (i.e. temperature control (lights on and off) at the low, midpoint, and high end of the specified range and the minimum, midpoint and maximum relative humidity control at the three temperature test points) will be made. While this testing is underway, light intensity, light uniformity, airflow and airflow uniformity tests as outlined above will be made.

**11.0 WARRANTY**

 The warranty period and requirements should be clearly specified.

COLLECTION SHEET

Contractor:

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 **RRES CONTROLLED ENVIRONMENT GROWTH CABINET SPECIFICATION B57**

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